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## THE ERECTION OF THE FORTH BRIDGE.*

By Mr. ANDREW S. BIGGART.

AT the Aberdeen meeting of this association, two years ago, I explained the method proposed to be adopted in the erection of the main steel piers of the Forth Bridge. Since that time this has been accomplished, and we can now take a retrospective view of the completed work. There arose as the work proceeded many points of interest not touched upon at that time, but if taken as a whole, the erection of the piers may be said to have been carried out on the lines then indicated, the only exception requiring notice being the mode adopted for building the internal viaduct. This was done in position, on the overhang system, instead of lifting it from the ground into place complete. While thus there is little further to add to my previous paper, a few remarks on points prominent during the actual erection of the piers should prove of interest. The progress made, as well as the working of the plant, was satisfactory. On some few occasions the piers and the platforms, Fig. 1, were raised as much as 48 ft. within eight days. The raising of the platform was done in stages of 16 ft., and those were accomplished in some instances within four hours. Frequent delays, more or less protracted, necessarily took place during the erection; for example, when the final adjusting of the columns was being carried out, previous to connecting the various bracings to these members. Before any of the permanent bracing of the piers was fixed to the 12 ft. sloping columns, Fig. 2, these had to be about 150 ft. high, and owing to their inward batter of 1 in 7½, their tendency was to lie toward the center of the bridge.

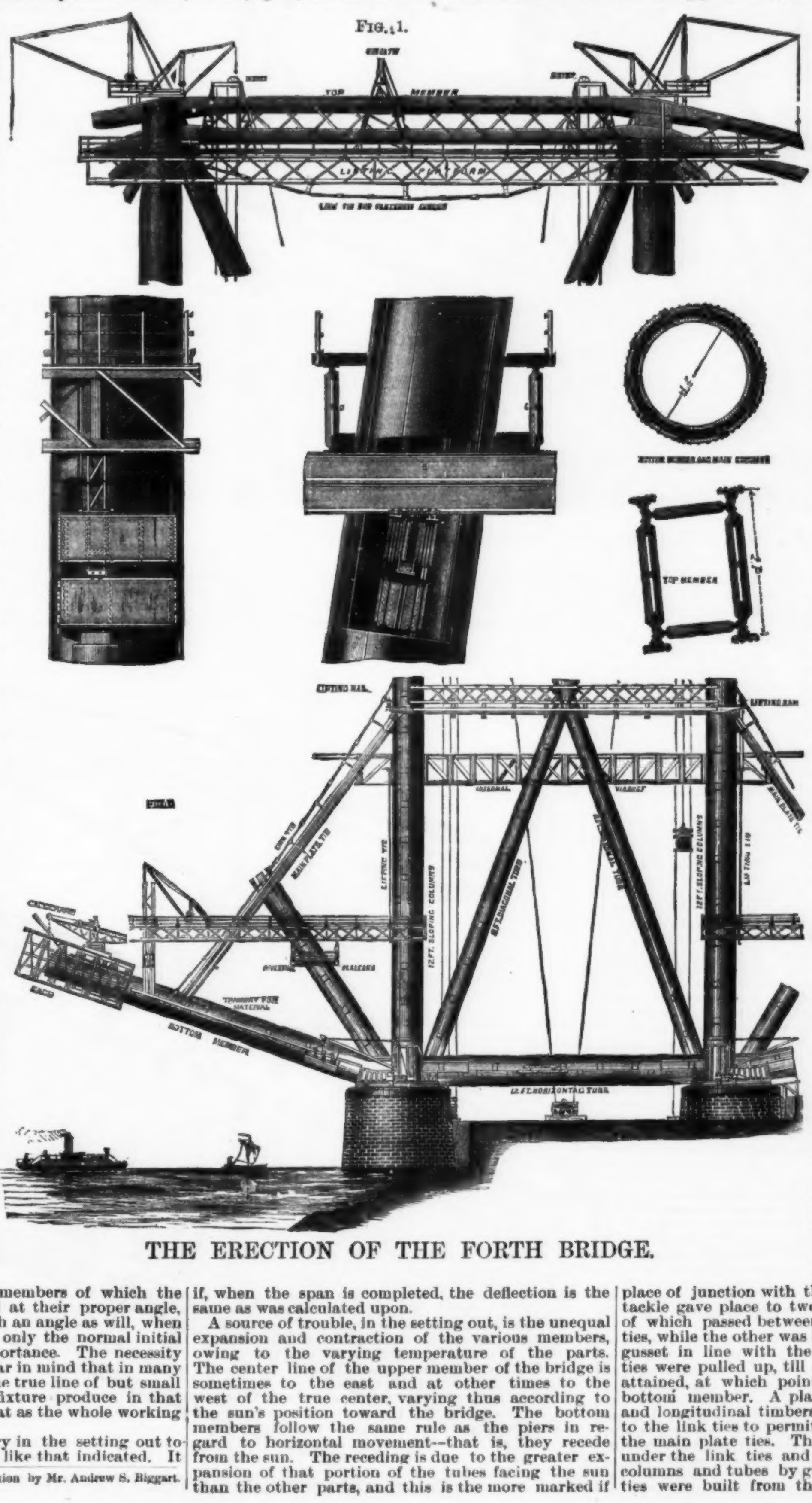
This, however, was found to be completely counteracted by the friction at the platform bearings, Fig. 3, preventing the blocks from sliding on the main lifting girders. So long as this lasted, these girders acted as effectual struts in keeping the columns apart. The result was also practically the same during the time the weight of the platform rested on the head of the hydraulic rams, Figs. 3 and 4, within the sloping columns, for these lay at all times nearly in the line of the columns themselves. Looking at these conditions, we were not surprised to find some of the columns come a little nearer to, while others went from, their true position in relation to the center line of the bridge. The columns were individually brought to their true position by means of hydraulic jacks, the platform for the time being resting on the top of the hydraulic rocking rams within the columns, for the purpose of removing the friction between the girders and their bearing blocks, and thus allow the movement to be made more easily. A part of the columns, near the bottom in each case, is left unriveted for the purpose of relieving any undue initial stress in these members. To make sure that the various members of which the bridge is composed are started at their proper angle, or are at least finally set to such an angle as will, when the bridge is completed, leave only the normal initial stress, is a matter of vital importance. The necessity for this is obvious when we bear in mind that in many members a movement out of the true line of but small amount will at the point of fixture produce in that member an initial stress as great as the whole working stress.

Hence, great care is necessary in the setting out to insure freedom from anything like that indicated. It will readily be seen how that in the setting of nearly the whole of the members many points arise which require to be carefully watched and calculated upon. Thus, the direction of the first bay of the bottom member must be such that when the junction of the permanent tie is made at its outer end, the member will be about 1 in. high at this point. The stresses at the lower end of the tube will then be the reverse of those at the same point during the time it supported its own weight. These, again, will be reduced to their normal amount if, when the span is completed, the deflection is the same as was calculated upon.

A source of trouble, in the setting out, is the unequal expansion and contraction of the various members, owing to the varying temperature of the parts. The center line of the upper member of the bridge is sometimes to the east and at other times to the west of the true center, varying thus according to the sun's position toward the bridge. The bottom members follow the same rule as the piers in regard to horizontal movement—that is, they recede from the sun. The receding is due to the greater expansion of that portion of the tubes facing the sun than the other parts, and this is the more marked if the sun has been shining brightly for a considerable time. Before the piers attained their full height, the erection of the cantilevers was begun, Fig. 5. The first parts started were the bottom members. These consist of tubes, and were built on the overhang system, without support, for a length of over 100 ft. At first a crane was employed to build the tubes. It was fixed in front of each skewback, and placed the plates and beams individually in position. As the building proceeded, the tubes were riveted up behind by hydraulic machines, very similar to those employed for riveting the 12 ft. sloping columns. The means adopted to carry the bottom members out further were now brought into use. A rectangular cage, carried at the end of each tube, and within which there is room for the riveting machine and the men at work, is the plan which has been adopted, Fig. 6. On the top of this cage is placed an hydraulic crane for lifting and placing the plates and beams in position and doing other necessary work. The material is brought within reach of the crane by a tramway running parallel with and fixed to the bottom member. The cage is rectangular in section, and is secured to the tube by strut and tie connections extending from the corners to rings encircling the tube at short intervals. In elevation the cage is composed of six braced rectangular sections securely bolted to each other, while in plan six series of bracings connect the two sides to one another. All the sections are exactly similar, and thus permit the interchange necessary as the work proceeds. This interchanging consists in removing two of the sections, when an advance requires to be made, from the back of the cage, and placing them in front by the hydraulic crane on the top of the cage. The hydraulic crane is of a simple form, and is capable of performing three independent movements—1. Lifting and lowering the load; 2, turning a complete circle; 3, traversing the full length of the cage.

The tramway consists of a continuous angle, resting on brackets bolted to the bottom member, Fig. 5. On it there is drawn backward and forward by means of a steel rope a carriage, to which is hung the material to be run out. The building of the bottom member was, as mentioned, continued without support, till the weight of itself and the plant on the tube raised the stress at the root to about 7½ tons per square inch. Temporary ties were then resorted to to furnish the necessary support. These ties were of two kinds—(1) A light link or carrying tie, and (2) the main plate tie. The link ties were carried from each side of the tubes to the 12 ft. sloping columns of the piers. They were attached both to the tubes and columns by gusset plates. So soon as these plates were fixed to the sloping columns the link ties were hung from them in sections, till they had reached their full length. The bottom end was now drawn out by tackle till near its place of junction with the bottom member. Here the tackle gave place to two large steel bolts, the one end of which passed between two channels bolted to the ties, while the other was held by a bracket fixed on the gusset in line with the tie. By these bolts the link ties were pulled up, till a camber of about 20 in. was attained, at which point they were attached to the bottom member. A platform formed of cross beams and longitudinal timbers was now secured by hangers to the link ties to permit of progress being made with the main plate ties. These were secured immediately under the link ties and at the ends attached to the columns and tubes by gusset plates. The main plate ties were built from the platform, beginning at the

FIG. 1.



THE ERECTION OF THE FORTH BRIDGE.

* Paper read before the British Association by Mr. Andrew S. Biggart.—*The Engineer.*

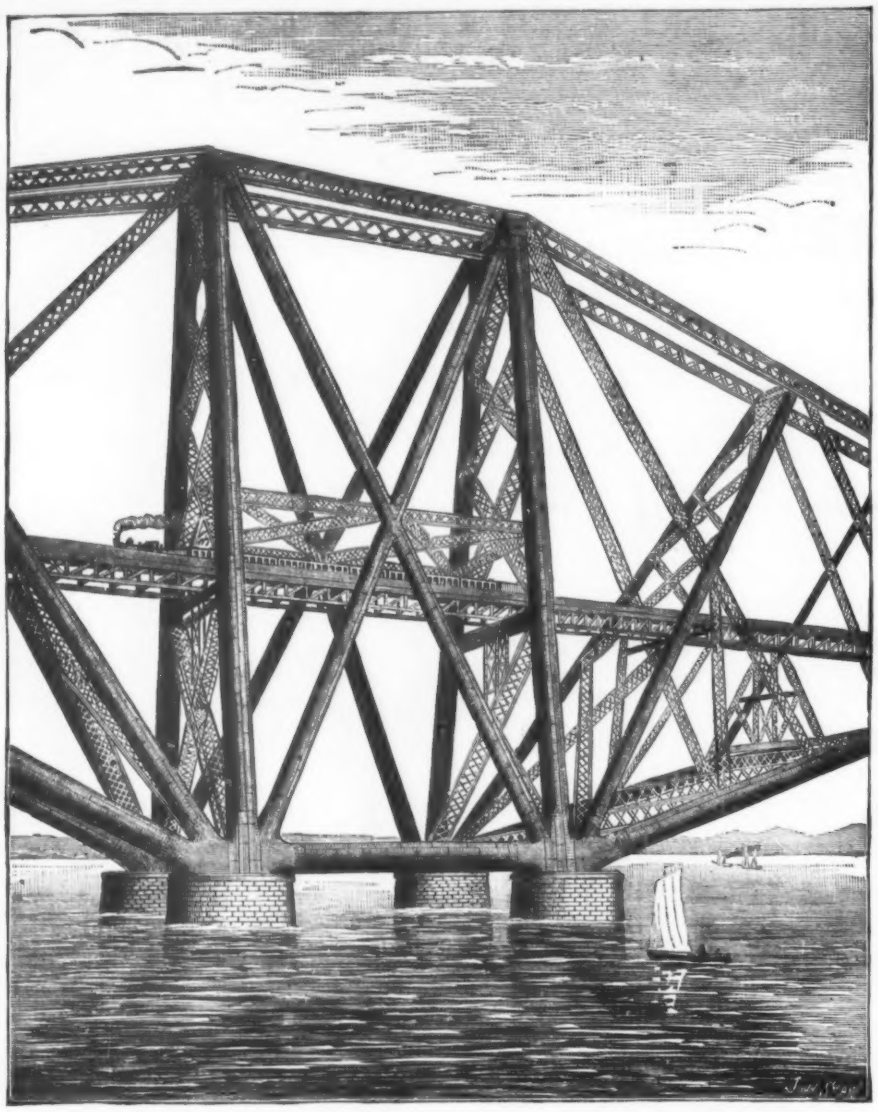


Fig. 2.—A MAIN CANTILEVER PIER—THE FORTH BRIDGE.

highest point. It is here worthy of notice that the platform and ties were in some cases built in position by means of the cranes placed on the main pier platforms 350 ft. above high water. On some other occasions they were lifted by tackle fixed to a temporary carriage on the link ties. In this case the platform for carrying the plate tie was built as the erection of the tie proceeded. So soon as the tie was completed it was connected to the gussets of the bottom member by bolts. It, however, remained free until the member should be raised by hydraulic rams to relieve the initial stress in the tube, and at the same time take up any slackness in the plate ties. The main plate ties between the sloping columns were raised in sections, and rested on platforms hung to the permanent bracing above their position.

As the first mentioned plate ties were built in position, the stress on the link ties increased, with the result that the bottom member rose. In this way the dip of the link tie became 4 ft. To raise the bottom member still further, two angles were bolted to the tie, on each side of the tube. They extended beyond the lower part of the tube, and served to fix a cross girder, on which two hydraulic cylinders were carried. Another girder was placed in front of these cylinders, having its bearings on the tube. On it a pressure of 120 tons was brought to bear, which, acting on the tube, raised it until the whole of the initial stress was practically eliminated in the free cantilevers. In the case of the fixed cantilevers the original stresses at the root of these members were not only relieved, but to a small extent reversed, on account of the tubes being much lighter. The gussets at the bottom of the main plate ties were now secured to the bottom member. It is interesting to follow the various vertical movements that take place in these bottom members. These are (1) a gradual fall, due to the weight of the tubes and of the temporary plant when being built out; (2) a rise, due to the pull occasioned by the weight of the link ties; (3) a rise, caused by the increased pull on the link ties when the platforms and main plate ties are placed in position; (4) a rise, as the hydraulic rams raise the member; (5) a gradual fall, on account of the stretching of the main plate ties as a weight of a portion of the first bays of the cantilevers and plant is transmitted to the ties; (6) a rise, due to a temporary pull, to be put in force before connecting the permanent ties; (7) a gradual fall, as the cantilevers are built out. This is intended to leave the bottom members with only the normal initial stress when the bridge is completed.

A start was made to the erection of the platforms, to be used in building the first bays of the cantilevers, so soon as the main plate ties were connected to the bottom members. They are in form rectangular, and consist of two parallel lattice girders connected together by cross and diagonal bracing, and the timber flooring on the top. These platforms—of which there are two for each cantilever—extend from the 12 ft. sloping columns, around which they are built, to the ties at the center of bay 1, bottom member. Provision is made for extending them by overhang, so that the building of the struts and other parts may be within range. The erection of the platforms and other temporary parts and placing them in position was a work which occupied a considerable amount of time. The main lifting girders were built on trestles, either in position or immediately in front of the skewbacks, and pulled along the top of the tube on cradles into position. This being accomplished, the platform girders were built immediately over the bottom members, on timbers resting on the tubes. These were then lifted by tackle or the hydraulic jacks until in a horizontal position over the main lifting girder. The platforms were then completed. The main lifting girders and platforms were now raised high enough to allow the jacks and cross girders, at the ties in the center of bay 1, to be fixed in position. All was now in order for the lifting to proceed, upon which the further raising was performed as described. The hydraulic jacks at the sloping columns each consist of a cylinder, piston, and hollow trunk, through which the upper part of the tie is made to pass. To the top of each cylinder a bow or crosshead is secured, through which also the tie passes. The jacks at the other end of the platforms are of the piston type. While the one end of the platform is supported from underneath, the other end is hung by two light ties, hanging from the hydraulic jacks at each sloping column. These jacks rest on a girder bolted to the main plate tie gussets. The upper part of the ties is composed of single and double bars alternately for a length of about 24 ft., and have cotter holes 12 in. apart. These bars are riveted to one another, while the lower end is bolted to the ties.

The lower part of the ties, again, is composed of standard lengths of flat bars, joined together by duplicate covers, and secured at the lower end to the platform girders. The aim in having two parts in each tie is to reduce the part through which cotter holes are cut. Cotters pass through these holes and transfer the load to the trunk or bow of the hydraulic jack, as the case may require. The permanent ties at the center of bay 1, to which the platform extends, are utilized as lifting columns during the time the platforms are being raised. When raising the platforms, what is done is to remove in single lengths at a time the flats in the lower parts of the ties at the sloping columns. This is effected by securing the ties at a point immediately under the lengths to be removed to temporary hangers underneath the hydraulic jacks, and while so held to remove the length between this point and the jacks. The upper part is now lowered and secured to the lower part. The platforms are raised 12 in. at each stroke of the jacks. To effect this, cotters were inserted over the trunks, and on water being admitted to the jacks these raise both ties and platforms. When the ties are lifted 12 in., the upper cotters are withdrawn and inserted 12 in. lower down. The water is then exhausted a little, which causes the platform to again rest on the hydraulic jacks. This action continued completes the lift.

Simultaneously with the raising of the end of the platform at the main piers, the other end, at the ties in the center of bay 1, has to be raised. The mode adopted is, however, wholly different from that just described. The columns at this point are rectangular. In each column, under the main lifting girder, there are placed three cross girders and a hydraulic jack. These cross girders extend from one side of the column to the other at right angles to the main lifting girder, and are secured to the column by steel pins. The jack is secured to the main lifting girder by a sliding block. Immediately underneath the jack, one of the cross girders is fixed to the column, while at the opposite side the other two cross girders are secured also to the column. The jack and the upper of the two cross girders are raised along with the main lifting girder when water is admitted to the jack. The

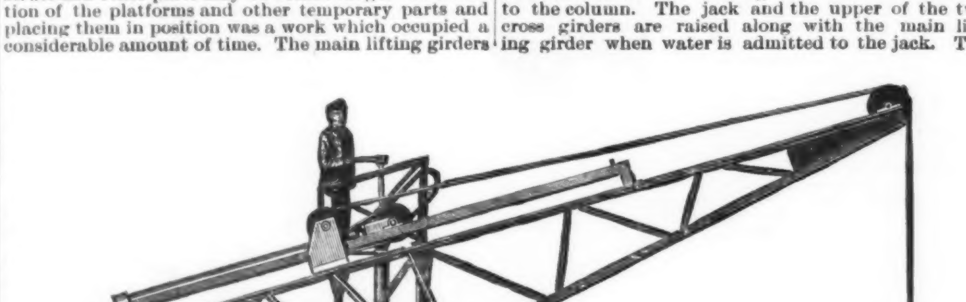


Fig. 6.—RIVETING CAGE—THE FORTH BRIDGE.

cross girder under the jack serves as the bearing from which to raise the platform. During the time of lifting packing is inserted between the girders as a security against a sudden drop should anything give way. The lower cross girders are now raised, and all is again ready for another lift. The erection of the struts and their bracings, the ties, and the other parts of the permanent structure is now partly proceeding from off these platforms in much the same way as has already been done in the case of the pier platforms. The first section of the bracing between the bottom members has been built out by overhang ties and other supports being brought into requisition to keep the work in position previous to the junction of the ends with the bottom members. As in the case of the piers, so in that of the cantilevers, much of the permanent structure is made use of in the erection. Thus with some small additions all the main lifting girders, platform girders, and temporary ties are parts of some of the last required members of the bridge. The weight thus employed will be about 1,800 tons.

While the foregoing are the lines on which the work has been carried out, it is well to mention that the details of work, similar at each of the three piers, have in a few cases been done differently at each pier. This is due at times to experience gained, in other cases to suit the varying circumstances, at the different piers. Apart from these causes the same minor plant is used, as much as time will permit, at each pier by transferring it from the one pier to the other, as its use can be dispensed with. From the experience already gained much that will determine the type of plant to be employed in the future work of erection has been learned. Thus, after due consideration, Mr. Arrol has, in consultation with Sir John Fowler and Mr. Baker, settled the principle on which the erection of the next bays of the cantilevers will proceed. This decision has been arrived at after carefully observing the work performed by some of the cranes on the pier platforms, at a height of 300 ft. above the work on which they were engaged, and in view of the time and cost taken in the erection of large platforms. It is not my intention to enter into this at present. Suffice it to say that cranes and light cages, or platforms, will be the feature of the proposed method. Advantage will also be taken of the internal viaduct, as a position from which much useful work can be carried out. Looking back on the work accomplished since the last time I was before you, and of which I have to-day given you but a faint sketch, everything confirms the opinion, then expressed, that the successful completion of the Forth Bridge will be an event of the near future. The engraving, Fig. 6, is from a drawing by Mr. Neville.

## THE CITY OF LONDON AND SOUTHWARK SUBWAY.*

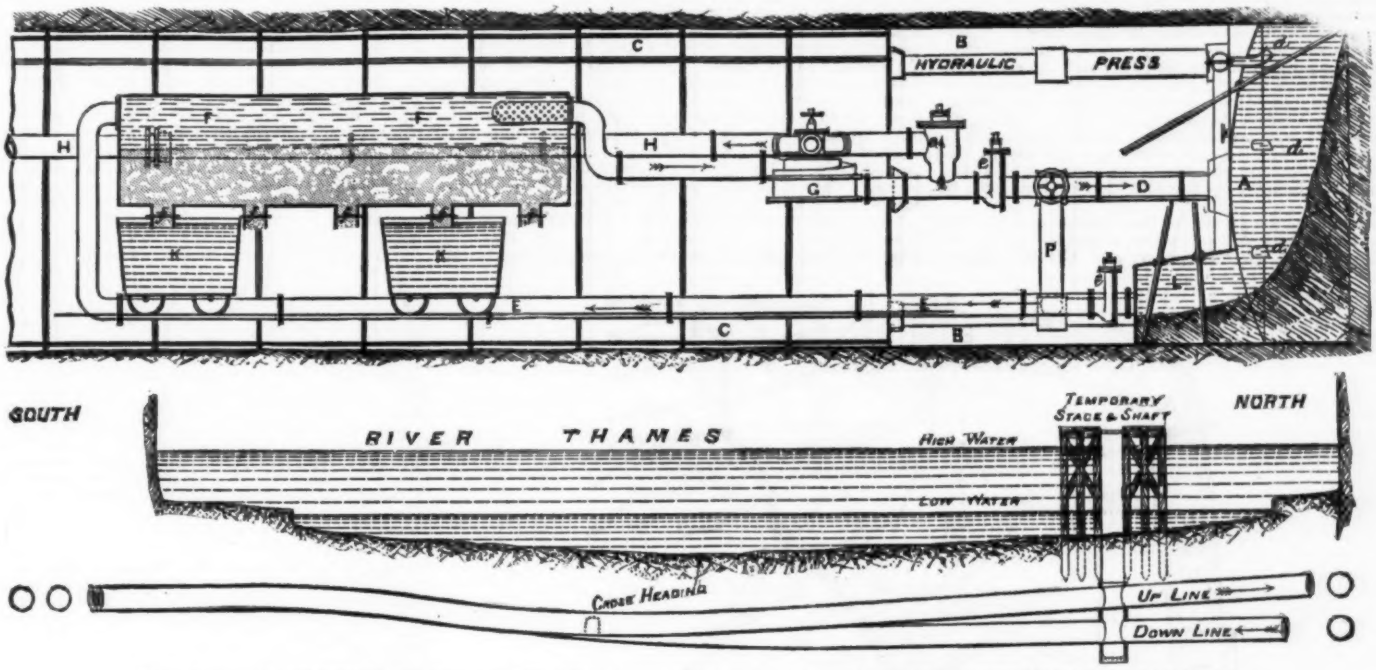
ON the south side of the Thames are some of the most densely populated districts of the metropolis, and beyond these are others of the most rapidly growing. The only direct communication with the City existing is that afforded by omnibuses traversing crowded thoroughfares, including London Bridge. The tramways from the southern, southeastern, and southwestern districts terminate about three quarters of a mile short of the City, because they have not been and could not be permitted to enter upon the overcrowded roads northward of Great Dover Street—see map. For the purpose of giving better access to and from the City, the Subway Company was incorporated by act of Parliament in 1884, and empowered to construct a double line of subway from King William Street to the "Elephant and Castle," Newington; and by an act of the present session the company has been invested with power to extend the line to the Clapham Road at Stockwell, as also shown on the map. The subway will then be rather more than three miles in length. The "up" and the "down" lines will be carried in separate tunnels placed at such a depth under the surface of the roads as to avoid all interference with sewers and other underground structures. An inspection of the map will show that, except where the line is under the river and an adjoining wharf, it will pass throughout its whole length under the streets, thus enabling it to accommodate the great stream of passenger traffic between the City and the Borough, Newington, Kennington, Stockwell, etc., now passing over London Bridge, without appreciable deviation from the present course of the traffic.

There will be stations at the Monument, King William Street; Great Dover Street; the "Elephant and Castle;" New Street, Kennington; the Oval, and Stockwell; and, if satisfactory arrangements can be made with the railway company, near the Brighton Railway Company's terminus on the south side of the Thames. At each station powerful hydraulic lifts are to be provided in addition to stairways for the purpose of giving easy and speedy access between the street and the platform levels; and in order to avoid double establishment on opposite sides of the road, at each station, the "up" and "down" tunnels will there be placed at different levels, so that passengers may pass readily from the lifts or stairs on one side of the road to either platform. The steepest gradient against the load will be about 1 in 30, but the line throughout the greater part of its length will be practically level.

Steam locomotives are not to be used upon the line. The act specifies that the "traffic shall be worked by means of carriages propelled upon the system of the Patent Cable Tramways Corporation, Limited, or by such means, other than steam locomotives, as the Board of Trade may from time to time approve." The endless cable system of traction has for some years been in successful use in a number of cities in America and elsewhere in connection with street tramways, and it is now being laid down in Edinburgh and in Birmingham—where it will shortly be at work—having been first introduced in this country on a small scale at Highgate. In this connection the system is hampered by the presence of the general street traffic and by the necessity of burying the cables in small tubes beneath the surface carrying the traffic, the attachment of the carriages to the buried cable having to be made through a continuous narrow slot in the street. In the subway the cable system will have a fairer field.

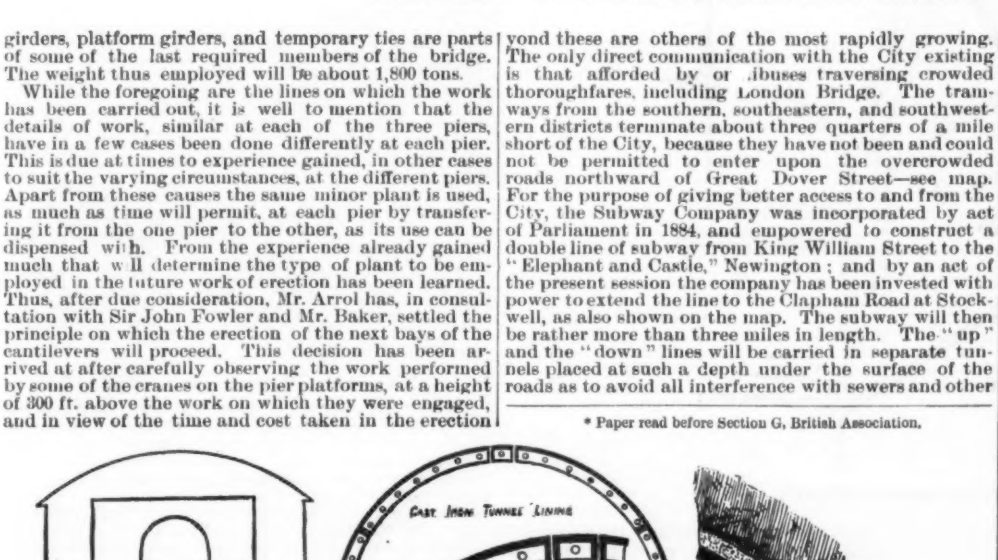
The cable system of working tramways has been so frequently described that it will suffice now to state that the endless cable passing from the hauling engine to the termini of the line upon one line of pulleys, and returning to the engine upon another line of pulleys, is kept in continuous motion throughout the period of working from the start in the morning to the stop at night. Along the course of the line the carriages are, by attaching themselves to or detaching themselves from this moving cable, continually starting, running, and stopping as their own or the general street traffic requires. By using one line of cable they run "up,"

* Paper read before Section G, British Association.




FIGS. 1 AND 4.—SECTION OF RIVER THAMES AND TUNNEL, AND PROPOSED TUNNELING APPARATUS.

## THE CITY OF LONDON AND SOUTHWARK SUBWAY.




FIGS. 2, 3, AND 5.—SECTIONS OF TUNNEL CYLINDERS, GROUTING APPARATUS, AND CARRIAGES.

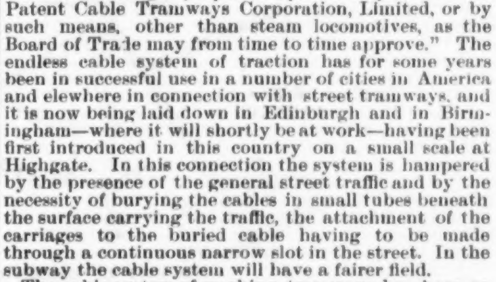



FIG. 6.—SECTION OF TUNNEL END AND SHIELD.

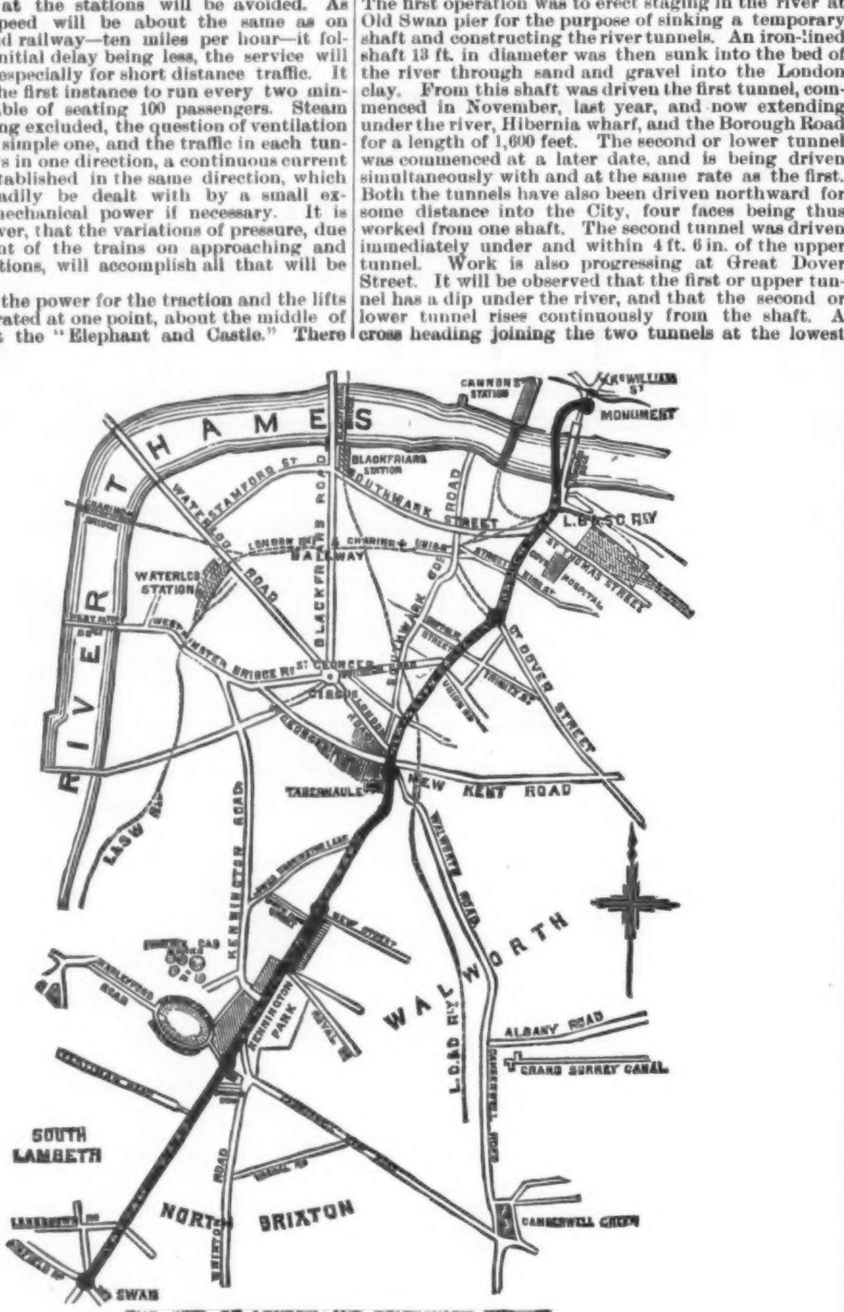
by using the other they run "down." Steep gradients have no terrors for them, and they pass up a hillside of 1 in 4½ at the same speed as they run upon the level. All moving independently, they are yet actuated from one station. This power of independent motion is secured by the use of what is termed a "gripper"—simply a pair of jaws actuated from the carriage by levers or screws so placed and adjusted as to close upon the moving cable when it is desired to start, and to release the cable when it is desired to stop. One great advantage of this mode of working in the subway is that light trains can be economically run at short intervals, in place of the usual heavy locomotive trains at longer intervals, and thus delay and accumulation of passengers at the stations will be avoided. As the average speed will be about the same as on the underground railway—ten miles per hour—it follows that, the initial delay being less, the service will be more rapid, especially for short distance traffic. It is intended in the first instance to run every two minutes trains capable of seating 100 passengers. Steam locomotives being excluded, the question of ventilation becomes a very simple one, and the traffic in each tunnel being always in one direction, a continuous current of air will be established in the same direction, which current can readily be dealt with by a small expenditure of mechanical power if necessary. It is expected, however, that the variations of pressure, due to the movement of the trains on approaching and leaving the stations, will accomplish all that will be required.

The whole of the power for the traction and the lifts will be concentrated at one point, about the middle of the line, viz., at the "Elephant and Castle." There will be two endless cables, one passing to and from the City, the other to and from Stockwell. Hydraulic pressure and return water pipes will be placed throughout the length of the subway for the working of all the lifts and any other small power machines in the subway.

The carriages are to be of the longitudinal type, with platforms and entrances at the end, similar to Pullman and ordinary tramway cars. They will be very commodious, giving greater height and width than the second and third class carriages in use on the Metropolitan Railway—see Fig. 5—and to each passenger about 30 cubic feet of capacity as compared with the 20 required by the Board of Trade regulation for railways. The stations are to be lighted by electricity, with gas in reserve. In connection with the permanent way no ballast will be used, and the absence of heavy locomotives will enable a smooth line to be maintained at comparatively small expense.

Having given this short description of the nature of the subway communication, the author will now proceed to give some details of the mode of construction of the works, and the appliances devised for driving through water-bearing strata should such be met with. The two tunnels, for the "up" and "down" lines, are absolutely separate and distinct between the termini, and are therefore capable of being carried in any desired position relatively to each other. Commencing side by side in the City, the "down" line falls more rapidly than the "up," in order that when Swan Lane is reached the former may be immediately under the latter, because, except in this position, they could not be constructed without encroaching upon private property or rights. In this position they pass under the northern foreshore of the river Thames, but before the southern shore is reached they are again side by side—as required by a clause in the act—and at each intermediate station, as already described, they are at different levels. The diagram—Fig. 1—shows the tunnels as they have been constructed under the river. Each of the tunnels is 10 feet in diameter, and is formed of rings of cast iron segments bolted together through internal flanges, as shown in Fig. 2. The rings are 1 ft. 7 in. long. All the flanges are 3½ in. deep and 1¼ in. thick. In the longitudinal joints thin strips of pine are inserted between the flat surfaces of the iron, and subsequently pointed with cement. The circular joints are made by tarred rope and cement.

The act for the first section of the subway was, as already stated, passed in 1884, but it was not until May, 1886, that the company, under the chairmanship of Mr. C. G. Mott, was in a position to go on with the work. The first operation was to erect staging in the river at Old Swan pier for the purpose of sinking a temporary shaft and constructing the river tunnels. An iron-lined shaft 13 ft. in diameter was then sunk into the bed of the river through sand and gravel into the London clay. From this shaft was driven the first tunnel, commenced in November, last year, and now extending under the river, Hibernia wharf, and the Borough Road for a length of 1,600 feet. The second or lower tunnel was commenced at a later date, and is being driven simultaneously with and at the same rate as the first. Both the tunnels have also been driven northward for some distance into the City, four faces being thus worked from one shaft. The second tunnel was driven immediately under and within 4 ft. 6 in. of the upper tunnel. Work is also progressing at Great Dover Street. It will be observed that the first or upper tunnel has a dip under the river, and that the second or lower tunnel rises continuously from the shaft. A cross heading joining the two tunnels at the lowest point of the first provides for draining that tunnel to the sump at the temporary shaft, whence the small accumulation of water will be discharged automatically by an injector hydrant, deriving its supply of high pressure water from the hydraulic main already referred to.




THE CITY OF LONDON AND SOUTHWARK SUBWAY.

The mode of constructing the iron tunnels is very simple, and can be described in a few words. A steel cylinder, overlapping—like the cap of a telescope—the forward end of the iron tunnel is provided near its front end with a strong diaphragm, Fig. 6, having an opening or door in it. Beyond this face project adjustable steel cutters, and behind it are ranged, round the circumference inside, six hydraulic presses, so fixed as to abut against the last ring of the completed tunnel. As the material is excavated from before the cap or shield by the miners and action of the cutters, and thrown back through the opening in the face, the shield is forced forward by the hydraulic presses. The shield thus clears out an exact circle somewhat larger than the outside diameter of the iron lining of the tunnel. The small annular space thus left is filled with grout composed of blue lias lime by means of an apparatus to be presently described. When the shield has been forced forward sufficiently far, a fresh ring of iron lining is built up inside and under cover of the overlapping steel cylinder. Six of these rings can be erected daily, representing a rate of progress of 9 ft. 6 in. at each face.

The apparatus for grouting is shown in section upon the wall. The lime is mixed with water in the cylindrical vessel, Fig. 3, the lid is closed, and compressed air at a pressure of about 30 lb. per square inch, from a compressor at the shaft, is admitted through the upper valve, when, the lower valve being opened, the contents of the vessel are discharged through a short length of hose pipe, a branch and a nozzle, into the annular space left outside the iron lining by the advance of the shield, holes being provided in each segment of the lining for the purpose. The grout is first of all forced through the lower holes in the segments until it appears at the holes above; the lower holes are then plugged, and the grout is forced into the next holes above, and so on until the grout comes out at the topmost hole, in which the nozzle is then inserted, and the grout forced in by the full pressure of air until the space is completely filled. Thus the iron lining is surrounded by a coating of lime or cement. The paddles upon the spindle, actuated by a handle, are kept continuously at work to mix the grout and to prevent its setting in the "grouting pan."

A somewhat similar mode of construction was employed in 1868-69 in executing the little tunnel under the Thames at the Tower, originated by the late Mr. Peter Barlow, and carried into execution by the author.

There, however, hydraulic and pneumatic power were not employed, and the area of the tunnel was considerably less than half the area of each of the present tunnels.

In the interval between that work and this, several not very successful attempts have been made in America to construct brick-lined tunnels with shields of similar construction to the one used at the Tower. When it is considered that an inch thickness of cast iron will offer a resistance to crushing as great as several feet in thickness of well set brickwork, and indeed in cases of small tunnels greater than any thickness of brickwork, and that at the same time it can be made perfectly water tight, it is surprising that no use has been made of iron as a lining for subaqueous tunnels and for tunnels where great strength is required, or when it was important to construct the work rapidly, without interference with street surfaces, or danger of settlement, and with a minimum of subsoil disturbance.*

In cases where tunneling has to be done through soft or loose material full of water, in place of the single opening in the shield, as already described, the arrangement shown in longitudinal section—Fig. 4—can be employed. The shield remains much the same, but the material is removed from its path by other means, viz., by a current of water aided by disintegrating protruding tools actuated from the inside of the shield.

Referring to Fig. 4, the cylinder, B, of the shield slides over the completed part of the tunnel, C. Through the front of the shield, A, a protruding tool of the form shown, or a revolving crosshead, or both, pass through stuffing boxes and assist in loosening the material in front, while water forced by the rotary pump, G, through the nozzles, D, scours out the *debris*, and carries it into the depositing tank, F. The *debris* settles in the tank, and the water is used over again. The circuit of the water being closed, the pump has no more work to do than overcome the friction of the pipes and give the required velocity to the current. To empty the depositing tank, the valves, EE, are closed, and tubs, KK, filled with water, are brought under the outlets, FF, so that the projecting lip of each outlet becomes immersed in the water. Upon opening the valve the *debris* from the tank falls into the tubs, while water from the tubs ascends into the tank to take its place. The pocket or chamber, L, is provided for the purpose of dealing with bowlders or larger pieces of *debris* than would pass through the pipes, and the face of the shield is put together in such a way that any portion of it can be taken down from the inside under air pressure when desired. In some cases the face may be divided into cells or compartments provided with tightly closing doors, one or more of which could be opened at a time for working on the material in front or clearing it of larger impediments, such as bowlders, air being in such cases forced into the material in front of the shield so as to displace the water therefrom.

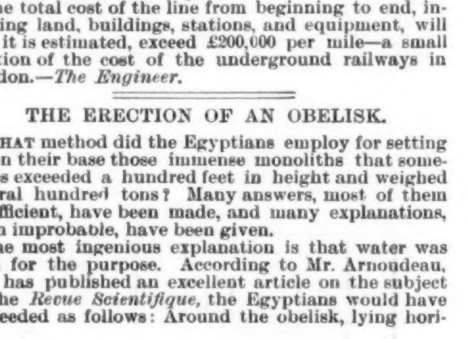
Sir John Fowler is the consulting engineer, and the main contract for the construction of the subway between the City and Newington is being carried out by Mr. E. Gabbutt, of Liverpool.

The total cost of the line from beginning to end, including land, buildings, stations, and equipment, will not, it is estimated, exceed £200,000 per mile—a small fraction of the cost of the underground railways in London.—*The Engineer.*

## THE ERECTION OF AN OBELISK.

WHAT method did the Egyptians employ for setting up on their base those immense monoliths that sometimes exceeded a hundred feet in height and weighed several hundred tons? Many answers, most of them insufficient, have been made, and many explanations, often improbable, have been given.

The most ingenious explanation is that water was used for the purpose. According to Mr. Arnoudeau, who has published an excellent article on the subject in the *Revue Scientifique*, the Egyptians would have proceeded as follows: Around the obelisk, lying horizontally with the base directed toward the pedestal, a circular dike was built to a height equal to that of the monolith, and having the already erected pedestal for its center. To the obelisk, especially to the upper part, were attached pieces of wood or any sort of float. The center of gravity being thus brought near the base, the monolith rose of itself in measure as the level of the water became higher in the immense reservoir.



This theory explains the facts very well, as may be seen from the following very simple experiment that any one can easily try. Take a flat-headed screw about two inches in length, and, after attaching a common cork to the end, lay it in a basin and then fill the latter

* A tunneling shield, substantially the same as above described, was used in New York several years ago in the construction of a section of tunnel under Broadway, near the post office. The tunnel was 9 ft. 4 in. in diameter, and a portion of it was made of iron plates as above described. The iron plate method, with brick lining, is also used in the Hudson River tunnels, now partly built under the Hudson River, between New York and Jersey City.—*Ed. S. A. S.*

with water. Our representative monolith will be observed slowly to rise, and, when the water has reached a sufficient height, it will stand erect.—*La Nature.*

## ASPHALT AND CONCRETE FOOT PAVEMENTS.*

By Mr. G. R. STRACHAN, Assoc. M.I.C.E., Chelsea.

THE object of this paper is to draw the criticism of the members of the association upon the experiments and experience of the writer and others on asphalt and concrete as materials for foot pavements, and, if possible, to induce others to carry forward experiments with a view to perfecting the use of these pavements. The writer desires to place in the forefront of the paper the fact that the credit of the Hornsey experiments herein referred to is due to Mr. T. De Courcey Meade, Assoc. M.I.C.E., who most readily placed them at the disposal of the writer for this paper; and also his obligations to the French Asphalt Co., the Val de Travers Asphalt Co., the Imperial Stone Co., and others, for the information given. Every pavement described has been personally examined by the writer, and the exact locality of each is stated, so that any one may examine them for his own information. Asphalt, properly so called, is a natural compound of carbonate of lime and bitumen, and is found principally in volcanic areas. Men of erudition have asserted that it was the pitch used to make the ark watertight, and that it was the slime used as a mortar in the construction of the Tower of Babel and the city of Babylon.

If such ancient uses of this substance are facts, its virtues were strangely lost sight of in the intervening centuries, for it is not till 1700 A.D. that its use became common. It was then used for the purpose of extracting balm from its beds, which was used for medicinal purposes, and was credited with superior healing powers. The origin of the asphalt beds has given rise to much speculation. A Swiss geologist has made an effort to explain their formation in a striking manner. Starting from the observation that all organic matter exudes bitumen in decomposing, he suggests that the beds are the remains of huge banks of oysters, the shells of which furnished the carbonate of lime, and the oysters themselves furnished the bitumen. As the asphalt beds are in some cases 27 ft. thick, and their areas are measured by square miles, it is evident that oysters were plentiful in those days.

The works of the French Asphalt Co. are described, as that company has executed all the asphalt works in Chelsea; but the writer wishes to say that the Val de Travers Co., Claridge's Asphalt Co., and others do equally good work. The mines of the French Asphalt Co., from which their English supply of asphalt is obtained, are situated at St. Ambroix, in the south of France. The asphalt is in seams, which lie nearly horizontal, and which have their faults, bends, etc., like coal seams. The bed and roof of the seams are of pure carbonate of lime rock, presumably the same as that of which the asphalt is largely composed. The seams vary from 3 to 5 ft. in thickness, and are worked by drifts from the outcrop on the hillside. The rock is mined by blasting and hand labor, and comes from the drifts in pieces measuring 1 cubic foot and downward. The asphalt then has a very dark chocolate color, and appears to be a tough, homogeneous substance, with striations of white matter running through it parallel to its natural bed, which are probably narrow seams of carbonate of lime.

When it is exposed to a hot sun, the surface will glisten with small fatty beads of bitumen, but at ordinary temperatures it is dry. After exposure to the air the surface turns a dull white color, owing to the evaporation of the bitumen; but this change is only skin deep. The rock is conveyed to Marseilles just as it leaves the mine, and is shipped to England. Formerly the beds of asphalt yielded a supply of natural bitumen, but twenty years ago the supply ceased, owing, it is believed, to some widespread cause, as several mines were affected in the same way at that time. At the depot of the company at Stratford the rock as delivered by ship is passed through a crusher which acts like a Blake's crusher, save that the solid jaw is replaced by a series of knives, and by which it is reduced to pieces not exceeding 3 in. in length. These pieces are poured into a Carr's disintegrator, which has spindles revolving 800 times a minute in opposite directions, and which reduces the asphalt to powder. The powder is screened through a rotary cylindrical sieve (144 to the sq. in.), and is then stored in sacks. The asphalt varies in the proportion of bitumen it contains. The richer parts are ground and stored separately from the other, and are afterward mixed in suitable proportions for the particular use to which they are applied. The following are analyses of asphalt rock of average richness at this stage:

| | No. 1 Sample. | No. 2 Sample. | Average. |
|---|---|---|---|
| Bitumen | 10·7 | 10·6 | 10·65 |
| Carbonate of lime | 88·05 | 88·15 | 88·1 |
| Silica | 0·55 | 0·4 | 0·48 |
| Alumina | 0·1 | 0·15 | 0·13 |
| Peroxide of iron | 0·2 | 0·1 | 0·15 |
| Moisture | 0·4 | 0·6 | 0·5 |
| | 100 | 100 | 100 |

When the asphalt is about to be used, the powder is poured into revolving roasters, and roasted for three hours at a temperature of 280° Fahr., during which operation the moisture is driven off. As the asphalt chars at 320° Fahr., care has to be exercised as to the proper temperature. It is loaded direct from the roasters into carts lined with sheet iron, covered with hemp cloths, and thus protected it retains its heat till it is taken to the site where it has to be laid. It is carried from the carts in baskets, spread over the foundation by means of a rake, and rammed solid by a series of blows from heavy heated rammers. The surface is ironed by a heated iron, which draws bitumen to the top, and in a few hours it is ready for traffic. This form of asphalt is known as compressed asphalt, and is the form always used for carriageways and frequently for footways.

* Paper read before the Association of Municipal and Sanitary Engineers and Surveyors, at Leicester.—*Iron.*

The other form of asphalt is known as mastic asphalt, and is a manufactured compound made up of natural asphalt, artificial bitumen, and grit. The asphalt is reduced to a powder as described. The artificial bitumen is used because of the scanty supply of natural bitumen. Its principal component is Trinidad pitch, to which is added from five to seven per cent. of shale oil. The mixture is boiled for twenty-four hours. The top liquid is ladled and is the artificial bitumen. It is a soft, viscous, black substance, which softens under the sun's rays. Its quality is tested by taking a piece between the fingers, and drawing it out to a string. If it does not snap until drawn out very fine, it is of good quality. The grit is obtained from Bridport, and is wholly composed of flint, very clean, and the pieces do not exceed one-eighth inch in size. The mastic asphalt is prepared as follows:

From 5 to 7 per cent. of artificial bitumen, from 20 to 30 per cent. of grit, and the balance in powdered asphalt, are placed in a covered caldron and heated for four or five hours. The mixture liquefies at 280° Fahr. to 300° Fahr. If it is to be used near the works (within ten miles), it is run into locomobiles (boilers on wheels), with a fire under them, and drawn to the site. When it is used, it should be hot enough to vaporize a drop of water. It is carried in pails and spread over the foundation by means of a float. Silver sand is then spread sparingly over the surface, and rubbed in by floats. In six hours the footway is ready for traffic.

One ton of asphalt covers twenty square yards when laid one inch thick. When mastic asphalt is to be laid at a distance from the works, instead of running it from the caldrons into the locomobiles, it is run into moulds, and moulded into flat cylindrical pieces weighing about fifty-six pounds each. These are taken to the site, placed in a caldron, from three to four per cent. of additional bitumen added to make up for the loss by evaporation, and heat applied to reduce it to a liquid condition. The laying is then performed in the same manner as before described.

This description may be taken as applicable to the method adopted by the Val de Travers Company, with a few variations in the proportions used. The following analyses of asphalts are of interest, as they are those of rocks of average richness:

| | Val de Travers Company. | French Asphalt Company. |
|---|---|---|
| Bitumen | 9·75 | 10·65 |
| Carbonate of lime, etc. | 89·75 | 88·85 |
| Moisture | 0·5 | 0·5 |
| | 100 | 100 |

The following analyses, in a different form, were placed at the writer's disposal by Mr. Meade:

| | Val de Travers. | | French Asphalt Company. | | |
|---|---|---|---|---|---|
| | Rock. | From Cheapside. | From Hornsey Lane. | From Crescent Road. | Rock. |
| Silica | 0·6 | 0·5 | 0·3 | 0·4 | 0·4 |
| Volatile organic matters (tar oils, etc.) | 5·8 | 5·8 | 6·5 | 6 | 8·2 |
| Non-volatile organic matters | 13 | 9·8 | 13·6 | 16·9 | 16·8 |
| Lime, etc. | 80·6 | 83·9 | 79·6 | 76·7 | 74·6 |
| | 100 | 100 | 100 | 100 | 100 |

This detailed description and the numerous analyses of good asphalts have been given so that spurious asphalts may be avoided.

In Chelsea there are 16½ miles of footway paved with mastic asphalt, having an area of 68,290 square yards. On the Queen's Park estate there are 41,500 square yards, which have been laid five years, and which are now in good condition, not having cost one penny for repairs. In King's Road, at Walpole Street, a length has been laid for seven years. The foot traffic over it is 7,500 persons in eighteen hours. At the end of the first five years it was cut open, and the wear was found to be such as had reduced the thickness to a spare seven-eighths of an inch, the original thickness being one inch full. On the east side of New Bond Street a length of mastic asphalt was laid thirteen years ago, between Oxford Street and Conduit Street, the thickness being three-quarters of an inch. The asphalt is now wearing through on to the concrete in the line of traffic at the forecourt line. The cost for repairs has been so trifling that it may be neglected. In this case the concrete foundation is as sound as before, and all that is necessary to restore the footway is to relay the asphalt, at about two-thirds of the original cost, when the pavement will be good for another thirteen years. As the traffic here is very severe and the footway narrow, it is reliable evidence of the durability of asphalt. The foundation for the asphalt footway is made with three inches of Portland cement concrete (six to one) of a very good quality. The surface is smoothed with the shovel, and four days are allowed for drying. The concrete has been laid hitherto without any joints. The mastic asphalt is floated over the surface, and the path is then completed. Mastic asphalt does not show any cracks on the surface. The concrete foundation, when the asphalt is removed, shows the irregular, tree-like cracks all along its length, branching from the curb to the back line, but the elasticity of the mastic asphalt is sufficient to resist the tearing action of the concrete as it contracts.

A study of the asphalt question resolves itself principally into a study of the movements of concrete when laid in long lengths, narrow widths, and small thicknesses. The writer inclines to the opinion that concrete has in itself a small power of contraction, apart from any considerations of temperature. The experiments of Dyckerhoff, which show that neat cement (slow setting) had an average expansive power over twelve months of 0·0734 per cent., and quick setting cements of 0·2019 per cent., and that concrete (three to one, sand) had an expansive power of 0·0264 per cent. (slow setting) and 0·0320 per cent. (quick setting), seem to show the contrary to be the case. The writer laid down a length of concrete (six to one, ballast) 52 feet long, 12 inches wide, and 3 inches thick, under a shed which had an open front, but so that the sun did not touch the concrete. The strip was laid on sand so as to give it freedom of movement. Another strip 26 feet long, of the same width and thickness (three to one, pebbles), and a third of the same dimensions (three to one, sand), were also laid under the same conditions. The only movement discernible, at the end of one month, was a slight contraction in length in all the samples. The uniform experience of concretes under asphalt is that cracks occur, which would tend to show that contraction, and not expansion, is the rule. At the same time, the writer has experience that concretes do expand, but this he attributes to the action of temperature. It is no uncommon thing to see the surface of an asphalt path raised crosswise in an irregular line, as though a small tree root was under it. In every case where the asphalt has been uncovered at those points by the writer, he has found the concrete crushed and the concrete on the falling level thrusting itself under the concrete on the rising level. This effect is most marked on hot days. In January last the writer laid some thousands of feet of asphalt path in St. Luke's Gardens, Chelsea. The sun is on it all day, and during the hot weather at the beginning of June, the number and size of these raised lines was astonishing. Shortly after midday they were most pronounced, and toward night they were less prominent. As a further evidence of the expansion of concrete under the sun's rays, the streets in the city can be named. The footway and carriageway are in asphalt on concrete. The expansion of the concrete in the carriageway presses the curb at the bottom. The expansion of the concrete in the footway presses the curb at the top on the opposite side, and the two have tilted up the curb in a marked manner. The writer has on a hot day taken up asphalt on a footway, and has found the heat much greater under the asphalt than on the surface. In order to avoid the expansion showing itself in footways, the concrete should be laid in sections, and the joints between them filled with some compressible substance.

Compressed asphalt has about one-third longer life than mastic asphalt under the same conditions. The cost is the same, but the use of compressed asphalt for this purpose has not been universally followed by reason of the cracks that appear on its surface. The cracks do not tend to spread under traffic, nor does the asphalt wear more at these parts than at others. They are unsightly, however. It is found that these cracks are exactly of the shape and in the position of the cracks in the concrete foundation. Compressed asphalt has no elasticity in itself, and when subjected to the contracting force of the concrete it is torn through. It is an admirable tell-tale of the movements of the concrete. Much ingenuity has been displayed in endeavors to avoid the cracks. The first step was to localize them. This was done by laying the concrete in twelve feet bays and in alternate bays, and filling up the screed space with fine concrete. The contraction then showed its effects at these places, with a result that a series of regular, straight cracks appeared instead of the irregular, tree-like cracks when the concrete was laid in one piece. These effects can be seen at many places in London, without specifying any particular place. Having localized the cracks, an experiment was made at Hornsey to avoid them. A strip of bituminous felt, six inches in width and three-quarters inch thick, was placed on the concrete over the whole length of the screed mark. This felt has much elasticity, and the object of the experiment was to ascertain whether it would take up the contracting movement of the concrete and absorb it. The length is laid at Crouch Hall Road, between Coolhurst Road and Clifton Road. The result has been that instead of one crack at each screed mark there are two, one on each side of the narrow strip of felt. It is evident that the concrete in contracting compresses the asphalt longitudinally, and that the cracks appear at the points where the opposing motions meet; and as the strip of felt represented a narrow area which was free from these forces, a crack appeared on each side where the forces took effect. In Archway Road, Hornsey, another experiment was made by covering the screed mark with a strip of mastic asphalt nine inches in width and one-eighth of an inch thick, just as in the last case with felt. For three months no cracks appeared, then a few slowly and at irregular intervals showed themselves, but during the severe winter of 1886-87 every screed mark showed its crack. These cracks were irregular in line, but they are confined in each case to the area covered by the mastic asphalt. These footways are laid on a three inch foundation of concrete.

In Marlborough Road, Chelsea, an experiment was made on different lines. A foundation of concrete 6 inches thick was laid, and the compressed asphalt laid on it. For four months no cracks appeared, but after that time they occurred at frequent intervals, though they are fewer than usually appear on a 3 inch foundation. When the asphalt and concrete were removed at the cracks, it was found that the crack extended through the whole thickness of the concrete. This experiment was based on the observation that cracks do not appear in compressed asphalt carriageways, and as the principal difference between the foundations in the footways and carriageways is the thickness of the concrete, it was assumed that it was the cause. The observation is, however, an incomplete one. In streets of light traffic the cracks do appear in the asphalt, as in Little Blenheim Street, Chelsea, and elsewhere. In streets of heavy traffic the cracks in the concrete tear the asphalt as they slowly form, but the traffic welds the asphalt together again before they show on the surface. In footways of heavy traffic there are fewer cracks than in those of light traffic, for a similar reason. At Muswell Hill, Hornsey, the experiment of covering the whole of the area of the footway between Onslow Rise and Grosvenor Gardens with bituminous felt was tried. The felt was in 3 foot widths, and was laid longitudinally with butt joints. At the circular curb the pieces were necessarily somewhat patched. The result has been that cracks have appeared at every joint of the felt with marvelous fidelity, owing to the movement of the concrete. In Whitehead's Grove,

Chelsea, between Marlborough Road and Keppel Street on the north side, a length was laid in 1885 on a 3 inch concrete foundation, which was covered with mastic asphalt ¼ inch in thickness. On this ¾ inch of compressed asphalt is laid. The mastic asphalt was laid to absorb by its elasticity the movement of the concrete without transmitting it to the compressed asphalt. It has survived two winters of great severity, and has lived twenty-one months without any cracks appearing. From this it would appear that the principle of a material between the concrete and the compressed asphalt which will absorb the effects of the movements of the concrete is a correct one, and the writer invites the members of the association to experiment on cheapening the method. The present result is an increase of life of 33 per cent., at an increase of cost of 12 per cent.

As evidence of the durability of compressed asphalt in footways, those in Cheapside may be named. They were laid in 1876, at a thickness of 1 inch, and are now wearing through. On the south side of the Strand, east of Wellington Street, 1 inch of compressed asphalt was laid in 1881, and has had only the most trifling repairs. The streets in the City, with the heaviest foot traffics in the world, are paved with compressed asphalt on the footways. The advantages of asphalt foot pavements are durability, a smooth surface unbroken with joints, a good foothold, even and regular wear, their impervious character, and the readiness and neatness with which they are repaired. They have a somber appearance, and show water on their surface longer than stone pavements. They wear to the last thickness without breaking up, and give a useful wear for the whole of their thickness. When a stone or other pavement has worn 1 inch, it may not be half worn through, but its useful life is over. Where there are cellars under footways, asphalt as a material for footways is unrivaled. In ordinary traffics, such as those named in King's Road (7,000 to 8,000 persons per day), an asphalt pavement can be laid 1 inch thick, with the certainty that for at least ten years it will need no repairs whatever. This pavement has also the advantage that the foundation is always preserved and good for use again when the wearing surface of asphalt has to be renewed. The following abstract of the present contract schedule in Chelsea will give the prices for these pavements:

| | Per sq. yd. s. | d. |
|---|---|---|
| Compressed or mastic asphalt 1 inch in thickness on 3 inches of concrete.... | 6 | 3 |
| Ditto, ditto, ¾ inch thick ............ | 5 | 6 |
| Compressed asphalt ¾ inch thick on ¼ inch of mastic asphalt laid on 3 inches of concrete.................. | 7 | 0 |
| Compressed or mastic asphalt 1 inch thick on existing concrete foundation (relay) ............... .......... | 3 | 6 |
| Ditto, ditto, ¾ inch thick.......... ..... | 3 | 0 |

These prices carry a guarantee of free maintenance for ten years. The vestry prepares the foundation for the concrete in new work at a cost of 2d. per square yard. The specification provides that the asphalt will be cut open at distances not exceeding 50 feet apart and the thickness measured. Five out of every six of these measurements must be at least the specified thickness, and the average of every six must be at least the specified thickness. The specification is strictly adhered to. The cost of the foot pavement in New Bond Street, already referred to, over twenty-six years, would be as follows, at per square yard:

| | s. | d. |
|---|---|---|
| Preparing foundation.... ................ | 0 | 2 |
| Laying concrete foundation and ¾ inch mastic asphalt.......... | 5 | 6 |
| At end of thirteen years, relaying mastic asphalt (life thirteen years)........ | 3 | 0 |
| Repairs......................................... | — | |
| Total.................................. | 8 | 8 |

or a cost per year, not including interest, of 4d. per square yard. It should be mentioned that the small cost for renewing asphalt footways is due to the fact that the asphalt is taken up as good as new asphalt after it has been cleared and prepared, and is reused for footways.

In dealing with the question of concrete as a material for foot pavements, the writer cannot claim such an experience of it as he has had with asphalt. In 1880, however, the vestry of Chelsea had laid by the respective makers a series of pavements in King's Road, against the Royal Military Asylum wall, and in 1885 a report was made on them by the writer. So many applications for copies have been made that it is now out of print, and as applications continue to be made, the results of the experiments are herein set forth for the information of the association. The writer holds that a knowledge of the manufacture of these pavements is useful information, and therefore he incorporates a description of the manufacture of Imperial stone pavements. The depot of the company is at East Greenwich, on the banks of the Thames. The aggregate used by the company is broken granite. Flint has been used, but the pavement in wear became very slippery. Kentish rag has also been used, but its wear was too rapid. The granite is broken so that it passes a 3-16 sieve. After screening it is carefully washed, as the dust acts as a coat round the piece, and prevents the cement laying hold of the granite. The washing machine is a slanting Archimedean screw, working in a trough, with openings in the thread of the worm. The water is run in at the high end, and the screened granite pieces put in at the lower. The screw churns the pieces over and over each other, and carries them up by its motion. The clean water meets the cleanest granite, and thus the pieces are not soiled by the dirty water they make. About 8 per cent. by weight is washed out as waste. The importance of a clean aggregate is seen when it is stated that briquettes made from washed pieces have a tensile strain of 15 to 20 per cent. higher than those made from unwashed pieces, when tested under similar conditions. The cement used is the best Portland, and is required to stand a tensile strain of 350 lb. per square inch after seven days' immersion in water. As a matter of fact, the cement used runs to an average of 425 lb. on the square inch. Hitherto a residue not exceeding 10 per cent. on a 50 mesh was allowed, but the value of increased fineness is recognized, and preparations are being made for a cement that will not leave a residue of 10 per cent. on a 76 mesh. The weight runs from 116 to 120 lb. per striked bushel. Before use, the cement is laid out to cool fourteen days, and is turned over frequently in that time. Great care is taken to keep the direct rays of the sun off the cement. The company exposed part of a sample of cement to the sun, and exposed the other part to the air. It was found that the part exposed to the sun showed a loss of strength equal to 50 per cent. The soluble silica used for the induration of the stone is a clear viscous substance made from pure flint and caustic soda, which are digested by heat under pressure in Papin's digester or an analogous machine. Its strength is technically known as 140° Twaddell, which shows 1,700 on a hydrometer. The silica is diluted with water until it shows 1,250 or 1,300 on the hydrometer, and is then a clear copper-colored liquid.

The stone is made of three parts by measure of washed granite and one part of cement. They are thoroughly incorporated in a dry state in a horizontal cylinder by machinery, and when this is secured, water is sparingly added, and the mixing continued. At each mixing there is made sufficient concrete for a 3 foot by 2 foot by 2 inch slab only. When it is ready for putting in the mould, the concrete does not appear to the eye to be sufficiently wet. The moulds are metal lined, true in shape, with clearly defined arrises. Before the concrete is placed into them they are oiled all over, and then placed on a trembler. This is a machine which gives a rapid vertical jolting motion to the mould. When the machine is started, the concrete is placed into the mould by small shovelfuls at a time, and two men with trowels spread it over the mould. When the mould is filled they pat the concrete with the trowels, the water rises to the surface, and an even, smooth face is secured. The mould and concrete are then removed to a rest for two days. The whole operation of mixing the concrete and making the slab in the mould is completed in six minutes. Machine-made stones are of necessity homogeneous, as veneering is impossible during the process. The slabs, when taken from the moulds at the end of the two days, are air-dried for seven or nine days, and then immersed in a silica bath for seven or nine days more. They are then stacked in the open for some months before use. The value of the silica bath is in hastening the hardening of the stone. At the end of a month the stone will stand from 30 to 40 per cent. more tensile strain if silicated than if air-dried only. It is doubted by Mr. Faija whether silicating increases the ultimate strength of concretes. The stone so prepared stands a tensile strain of 650 lb. on the square inch when three months old. Strains of 1,000 lb. have been obtained, but they are not the average. The value and excellence of this concrete is shown by the fact that, though the neat cement has 75 per cent. of aggregate added to it, yet in three months the mixture bears nearly double the tensile strain of the neat cement after seven days. The writer was shown the original of a report by Kirkcaldy, dated September 6, 1882, in which one sample of stone took 8,075 lb. per square inch to crush it, and another reached the marvelous strength of requiring 9,492 lb. per square inch to crush it

In the King's Road experimental pavements the makers laid their pavements with the knowledge that they were competing with their rivals. They were laid in 1880. Asphalt, York stone, Ferrumite stone, Victoria stone, and Imperial stone were laid side by side and subjected to the same traffics. The writer includes the York stone results, though not strictly coming within the subject of the paper. In June, 1884, the Ferrumite stone was removed, as its slipperiness had become a source of danger. Its area was taken by Wilkinson's granite concrete pavement and by Shap stone pavement. After five years' wear of the orginal stones, the following rssults were obtained:

The York stone occupied an area of 87 square yards; the original thickness was 3 inches; the number of stones 123, of which after five years' wear ten had broken edges, sixteen had broken corners, twenty-one had their surfaces peeling off, and six were worn so as to be dangerous. The wear was not measurable by reason of the uneven thickness of the stones, but it was unmistakable. The foothold was good in all weathers. The actual cost was 8s. 7d. per square yard laid. The Victoria stone occupied an area of 81½ square yards; the original thickness was 2 inches; the number of stones 168, of which thirty-five had broken edges and corners, two had their surfaces peeling off, and three were visibly cracked across. The wear was not quite ⅛ inch at the greatest traffic line. The joints of the stone were pleasing, and the color cheerful. The foothold is not so sure as that of York stone in dry weather, and in a drizzling rain it approaches slipperiness. The cost was 6s. 4d. per square yard laid. The Imperial stone occupied an area of 90¼ square yards; the original thickness was a full 2⅛ inches; the number of stones 187, of which eighteen had their corners and edges broken, and one had its surface partly peeled off. The wear was not quite ⅛ inch at the greatest traffic line. The regularity of the joints is pleasing to the eye, and the color is light and cheerful. The foothold is more sure than that of the Victoria stone sample, but it becomes somewhat slippery in drizzling rain. The cost was 6s. per square yard laid. The experience gained with the Shap stone laid in 1884 is more limited, but the stone does not appear to be better than the concrete stones described. The length laid *in situ* by Messrs. Wilkinson is subject to the same remark, but the aggregate is already wearing up. It is laid in 8 foot bays. A repair made in it is a great dissight to it. The effect of the traffic in wear is visible.

Mr. Walker, of Leeds, has laid down (1886) in King's Road a short length, in bays about 4 feet square. It has a very smooth surface, and appears to be a very good pavement. He lays a foundation of ballast concrete 2⅛ inches thick to within ⅛ inch of the finished surface, and cuts roughly through it, so as to form the bays. He then floats the surface with a fine rich concrete, made of one part of cement to one or one and a quarter parts of crushed granite or slag, which pass through a $\frac{1}{12}$ sieve. This is then cut through with a knife into bays of small areas. The foothold is fairly secure and the wear very satisfactory. No cracks appear when the bays are made less than 10 feet square. At 322 Oxford Street, a piece has been down three years, and no wear is visible. He claims that his fine rich concrete on the surface attains more nearly to the texture of York stone than any other pavement. The joints, however, have a tendency to spread. Concrete pavements laid in the slabs have two serious disadvantages. The writer's experience refers to Victoria stone, but there is no reason to suppose that slabs of other make are free from them. The first is the annoyance caused by the hard metallic sound of the footfall on them, which is especially noticeable at night. The other is their brittle nature and the presence of hidden cracks after wear. When taken up to relay, it is often found that a stone which was apparently sound breaks before it can be relaid. Concrete pavements *in situ* have the serious disadvantage that they cannot readily and cheaply be repaired. A patch in them shows for the whole life of the pavement, unless a whole bay is removed.

The writer is of the opinion that concrete pavements *in situ* are preferable to concrete pavements laid as slabs. There is, however, no reason why this pavement should not be laid by surveyors themselves, without the aid of a contractor. Much has to be learned before concrete as a material for foot pavements is perfected, but that can most readily be learned by each engineer doing his own work and exchanging experiences. The prices paid for concrete pavements are very great. One stone is advertised for 7d. per square foot, which equals £4 14s. 6d. a cubic yard. This is an extravagant price to pay for concrete, even if it be of the very best kind, and silicated too. Concrete for foot pavements has its own field, and within well-marked limits its use is advisable, but until its capabilities are more largely tried and its usefulness increased, the full advantage will not be obtained from it. The price stated is large enough to cover the cost of experimenting, and the writer trusts that the members will carry out such a series of tests and trials as will complete the knowledge of concrete as a material for foot pavements.

## WOOL HAT MAKING.

WOOL WASHING.—Considered in the abstract, this is, of course, the first process connected with the hatting industry; but, as such, is rarely undertaken by hat manufacturers. Practically, therefore, it may be said to constitute an entirely separate industry. For this reason it has not been thought desirable, in the present connection, to devote to an outside subject the space which a detailed description would occupy. The hat manufacturer, ordinarily, has the wool washed for him, and from the moment that the material, thus prepared, is put into his hands, the making of a wool hat may be said to commence.

CARDING AND FORMING.—The carder used in this business is, in all respects, identical with that employed in the cotton trade. Indeed, the ordinary cotton carding engine answers the purpose perfectly, and it is extensively used by hat manufacturers. As the wool leaves the machine in the orthodox tissue form it is received by women, who carry on this part of the work, and is spread evenly over the double cone shown in our illustration (Fig. 1). By this method two hat bodies


FIG. 1.

are in course of formation at the same moment. There is no system of determining when a sufficient weight of wool has been put on the cone in layers, except that which is derived from the practiced touch of the operator; but, as in all such operations, it is seldom that the practiced hands of a good former in the hatting trade ever deceive her as to the weight of a body under manipulation. While the machine pays out and the cone receives the material, the busy fingers of the girl never cease guiding and superintending its even distribution, so that the requisite and uniform thickness may be given to each of the two bodies in course of formation. When a sufficient weight has been laid on, the division of the hitherto twin bodies is effected by means of a pair of sheep shears. The points are inserted in the groove which runs round the thickest part of the circumference of the cone, and, as it revolves, five or six slashes suffice to separate the double body. The cone is stripped, and the manufactured article is placed upon a convenient bench in the rear, there to await the operation of being tested on the scales. Meanwhile, the liberated end of wool, which the carder goes on delivering, is again placed on the cone for the formation of the next pair. The box at the foot of the illustration contains a series of cam motions, which impart a "drunken" or tumbling motion to the cones. The rollers, which give a rotary action to the cones, have themselves a rotary action individually; but, taken as a whole, they have a reversing action, which is derived from the upright shaft. The weighing of each hat separately, which next follows, and the slight reduction in weight which has usually to be brought about, are both processes which consume much time, and cause considerable waste of material. The exercise of a little ingenuity might save both these operations.

HARDENING.—This is the first process of felting. Up to this point the hat body exists in the shape of a flimsy woolly substance, and in size absurdly out of all proportion to the head which it will ultimately cover. To give the character of felt to this substance and to begin the necessary reduction in the size of the body

are now the objects in view, and these are accomplished by the process technically termed "hardening." Of this there are two methods, called respectively "flat" and "cup and cone" hardening. It is proposed to take them in this order, and describe first:

*Flat Hardening.*—To produce felt from wool, the three things required are heat, moisture, and friction. Fig. 2 shows how these are applied. The hat bodies are placed upon the table, and the plate is then dropped upon them. A rubbing motion is then communicated to the plate through the medium of a crank upon the pulley shaft, transmitted through a connecting rod carried by a secondary shaft, and which is extended above the latter—a short link imparting motion to the rubbing plate. A few minutes of this treatment turns out the body in a sufficiently felted condition to be fit for a subsequent operation of a more drastic character. A defect in this machine exists in the fact that hat bodies hardened on the "flat," while being thoroughly done in the body, are found insufficiently finished about the crown. It becomes necessary, therefore, to operate upon that part by a separate process. The method of accomplishing this is shown in the immediate foreground of the illustration. The hats are drawn on to the cone, which is heated by means of a steam pipe shown on the right, and the rubbing disk does for the crown precisely what the flat rubber has already done for the lower parts of the hat. The power for the crown rubbing is applied in precisely the same way as for the flat process on the table, the connection being plainly indicated in the figure.

*Cup and Cone Hardening.*—This method has at least one advantage over that just described, inasmuch as the whole operation of hardening—body and tip alike—is accomplished by a single process. Figs. 3 and 4 show the cup and cone in each of the respective positions which they occupy during the entire operation. The hats, three at a time, are pulled over the cone, and the cup having been thoroughly heated is then placed over them, and the rubbing or felting motion communicated in a manner to be described. The figure on the extreme left of Fig. 4 shows a section of the cup in position, the cone which it surmounts being covered with

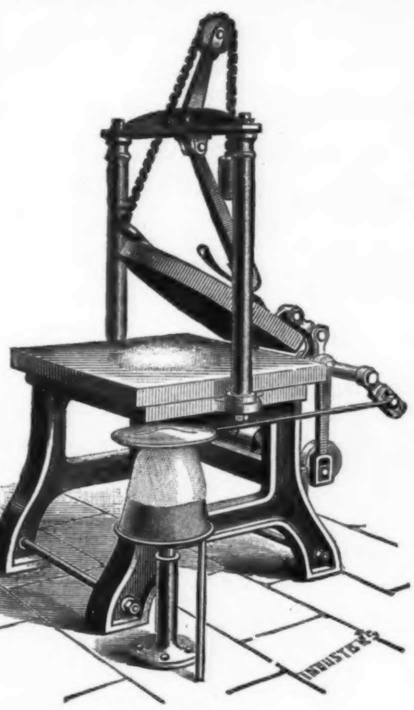


FIG. 2.

its complement of bodies requiring to be hardened. The next figure shows how the requisite heat and moisture are communicated to the cup previous to its being placed in position. The third and fourth cones are those upon which hat bodies have been drawn, and these are waiting for the cup or rubber. The fifth figure shows the heated cup lifted from its steamer and in the act of being swung round into position for dropping upon the prepared cone. The figure on the extreme right side shows the complete apparatus arranged for rubbing. The end view (Fig. 3) represents the motion employed, the dotted lines showing how the rubbing action is effected. Motion is derived from the horizontal shaft, which runs at an elevation level with the top of each cone. This is oscillated slightly by a crank on the pulley shaft, shown on the extreme left. The crank connected with the shaft, which is seen between the two end cones, receives an increased motion from its extra leverage, and shakes the cup, while the core is kept revolving by means of a worm wheel.

SETTLING.—Science has not yet supplied mechanical means for accomplishing the operation of "settling," and the present generation of hatters are working on pretty much the same lines that their grandfathers followed as regards method. The vitriol, which forms an important element in the process, is intended to roughen the fiber, so that a perfect felt may be obtained. On the sheep's back each fiber of wool grows perfectly straight, and the fibers have, under all conditions, a strong tendency to remain in this exact shape or condition. Felting, therefore, remains an impossibility until this natural tendency has been dealt with and overcome. The horny and smooth coating of the fiber requires to be roughened, and this can only be done by the action of an acid. A diluted solution of vitriol and water has been found best to answer the purpose in view. The copper or boiling vessel employed contains a hot liquid having the proportion of half a pint of vitriol to six gallons of water. The "plank," or sloping woodwork which surrounds the copper, is adapted for four operators, and each of these works upon four hats at once. The hats are laid flat, one upon another, dipped into the boiling liquid, brought back to the "plank," and rolled round a wooden roller with as much force as a man can exercise. Alternate dippings and rollings are carried on for about fifteen minutes, and when the bodies are considered to have had as much of the acid forced into them as the material requires, they are then made ready for milling. One of the most striking facts in connection with the settling and subsequent operations, indeed, of the great majority of the various processes through which a hat passes in the course of manufacture, is the intensity of the heat to which it is subjected. Mr. Watson Smith has stated that wool is decomposed when heated to more than 150 degrees Fahrenheit, so that it would appear as though the original nature of the wool must be wholly destroyed. But on the destruction so brought about a hat is created which at least looks well, wears, and answers every practical purpose. What could be realized from a scientific and an artistic standpoint, by a re-

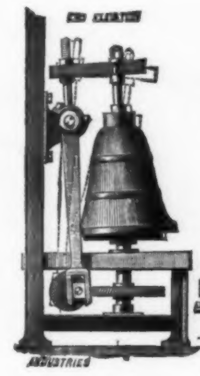


FIG. 3.

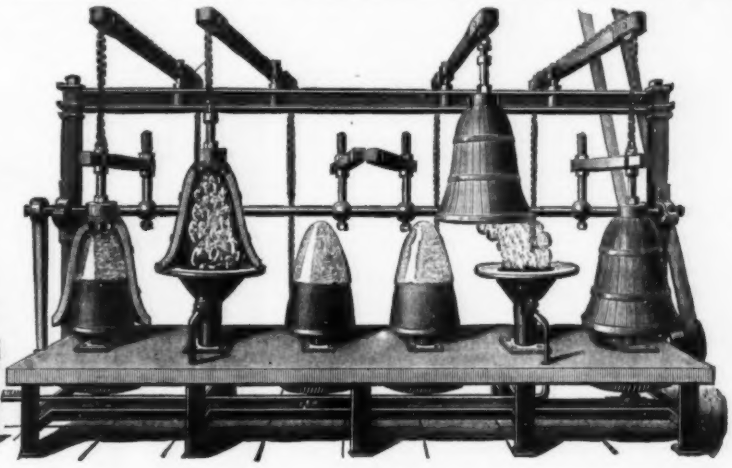


FIG. 4.

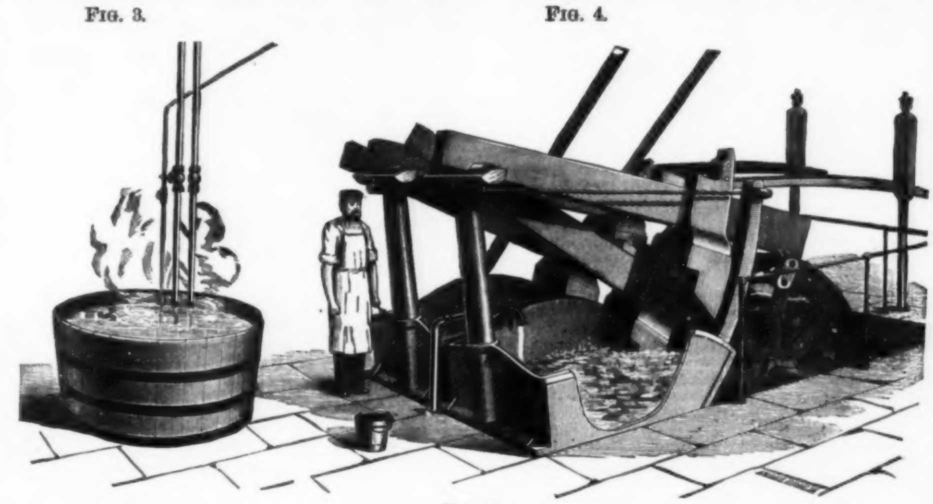


FIG. 5.

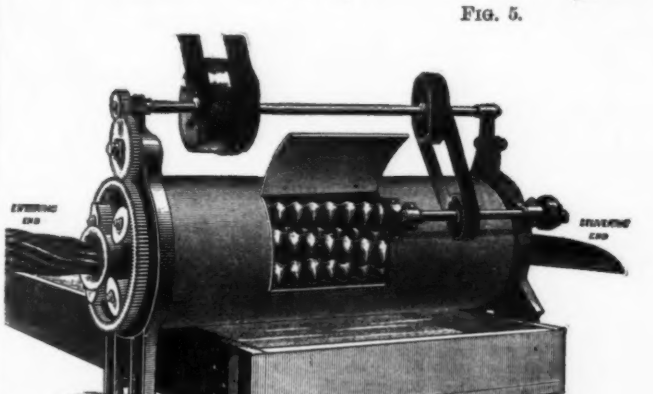


FIG. 6.

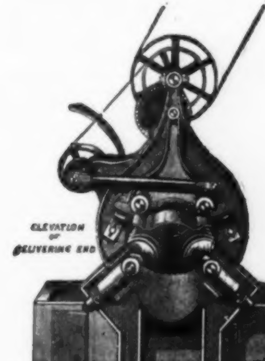




FIG. 7.

## WOOL HAT MAKING MACHINERY.

constructed method of manufacture, is at least an interesting query. A practical manufacturer's contention is that with only 150 degrees of heat it is impossible to get either the dye or the proof or "stiffening" into the body to a sufficient extent to turn out a hat which is fit to look at when finished. But it is greatly to be feared that the practical manufacturer of to-day is, as a general rule, very little of a scientist. It may, however, not be past hoping for that the future may produce a man who can manufacture a really good hat without insisting upon the preliminary necessity of destroying the nature of the material of which the article is made. There is, at all events, scope in this direction for the best energies of those who have most interest in the question.

BUMPING AND WASHING OUT.—This process is ordinarily known in the woolen trade as milling, and the machine which is here called a "bumper" may be recognized in another connection as a pair of milling stocks. The object in view is to solidify the body by milling up. As may be supposed, therefore, a considerable diminution of the body takes place in this operation, which, as will be seen by our illustration (Fig. 5), is accomplished by the beating it receives by the alternate blows from four heavy wooden hammers. The beams which carry the bumping blocks are lifted by means of lugs carried upon wheels or disks upon the main shaft, such wheels having lugs placed alternately upon both sides, so that alternate action may be given to the bumpers. It has two receptacles for hat bodies, each of which is capable of receiving fifty dozen hats at a time, so that one hundred dozen are under treatment at once. This appliance, it will be seen, is equal to a large output. Water is turned into the receptacles, and thus much of the acid with which the bodies were charged in the last operation is washed out. The washing out process is, however, completed afterward by means of the large vat shown in the foreground. The bumping being completed, the bodies are shoveled into the vat and subjected to a thorough washing with boiling water, so that the last remains of the acid may be entirely removed. This is a necessary preparation for what is to follow, because, until the body has been denuded of its acid, it is not in a fit condition for absorbing the "proof" with which it is shortly to be charged, and which is a necessary preparation in order that a permanent shape may be given to it.

TWISTING.—Twisting may, for all practical purposes, be described as the last operation of felting. The machine in which this process is carried on is shown in side and end elevations respectively in Figs. 6 and 7. The opening in the lid of the cylinder in the side view is introduced to show the exact positions of each of the four serrated rollers contained in this machine. The diameter of these rollers is less at the center of their length than it is at the end. The centers of the two lower rollers are fixed, but the centers at the delivery end of the two upper rollers are made to oscillate,

The controlling motion will be seen more clearly in the end view, being transmitted from the main shaft by means of a short countershaft. The bodies are taken fresh from the washing out vat and run through this machine from end to end. Having been subjected to the action of this machine, the bodies emerge reduced, in a general sense, to the actual size required for being felted into hats. In short, the conditions desired in a hat body, viz., shape, size, and substance, are now given to the wool; and every subsequent operation may be considered as generally partaking of the nature of a finishing process.

STRETCHING OR STUMPING.—In order to ascertain its exact suitability as to size and condition, each body is now taken in hand by the men who work at the copper referred to in the "settling" process. Boiling water is again brought into requisition, and each body is first laid upon the "plank" and its size ascertained by means of a hatter's measuring stick, which consists of a flat piece of wood with marks roughly cut upon one side. If the size is satisfactory, each article is passed. If otherwise, a few dippings into the boiling water, and a corresponding number of rollings on the plank, soon put right any small imperfections. Each body is then again dipped and given an additional rub, in order to produce a face on its exterior. This is the beginning of that sightly appearance and pleasant touch which are the most marked indications of excellence of workmanship in a well made and properly finished wool hat.—*Industries*.

## ROBURITE, THE NEW EXPLOSIVE.

ON the 27th of October, further trials took place in the Durham district—at the Marquis of Londonderry's colliery at Silksworth, and the Earl of Durham's at Bunker's Hill, near Newbottle.

Early in the morning several shots were fired at Silksworth in stone, at a very considerable distance from the bottom of the shaft. Of these some were for the purpose of clearing out the stone, while others were "blow out" shots purposely contrived so as to give the greatest chance of showing flame or spark. None was, however, to be perceived, although the observers were only eight yards distant, and, in all cases, the safety lamps were carefully covered. The manager of the colliery expressed himself as highly pleased with the efficiency of the roburite in hard stone work, which he considered to be quite as great as that of dynamite or blasting gelatine. The most remarkable trial at Silksworth was in what is called a "staple," or opening for a short shaft. Three vertical holes were drilled to a depth of 2 ft. 6 in. in the rock, and each charged with a roburite cartridge of 60 grammes (⅛ lb.) Two of these were exploded simultaneously, and the third soon afterward. The result of these shots—they blew out a mass of stone 3 ft. in depth with a horizontal section of about 7 ft. long by 6 ft. wide; that is, extending to a depth of 6 in. before the bottom of the drill holes. In addition to this, the stone below was more or less loosened to the depth of another foot, so that it could be got out with the pick.

Later in the day a series of gas experiments were carried out at Bunker's Hill, which is under the management of Mr. Leishman. The arrangements for measuring the proportions of coal gas and atmospheric air to form an explosive mixture were very similar to those at Wharncliffe Silkstone Colliery the week before. A temporary gasometer was constructed with two casks, but, instead of a boiler tube, a large vat was employed to contain the firedamp so produced, and inside this vat the various charges were fired, its open top being closed by nailing over it large sheets of thick brown paper. The following were the shots fired, the cask each time being previously filled with an explosive mixture of gas and air:

1. A charge of roburite covered with very fine coal dust was exploded by electricity. There was no ignition of the firedamp, nor was any flame or spark perceptible.

2 and 3. Repetitions of No. 1, with a like result.

4. In the cask was placed a roburite cartridge covered with loose gunpowder. The gunpowder ignited, firing the gas. There was a vivid sheet of flame, and the cask was shattered into small fragments.

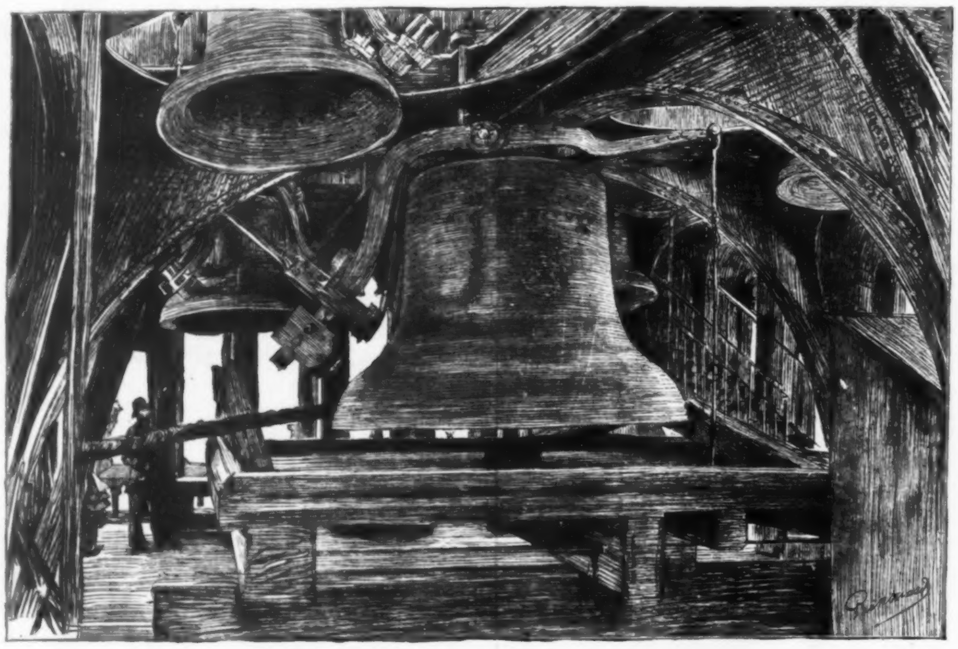
5. A charge of ordinary blasting powder was fired by electricity in another cask filled with firedamp. The latter was ignited with a vivid sheet of flame, but the cask was not shattered. (N. B.—It is, of course, admitted on all hands that gunpowder will ignite firedamp.)

6. A charge of blasting gelatine—inclosed in Settle's water cartridge—was covered with loose gunpowder. The latter was not fired, nor the explosive gas inflamed.

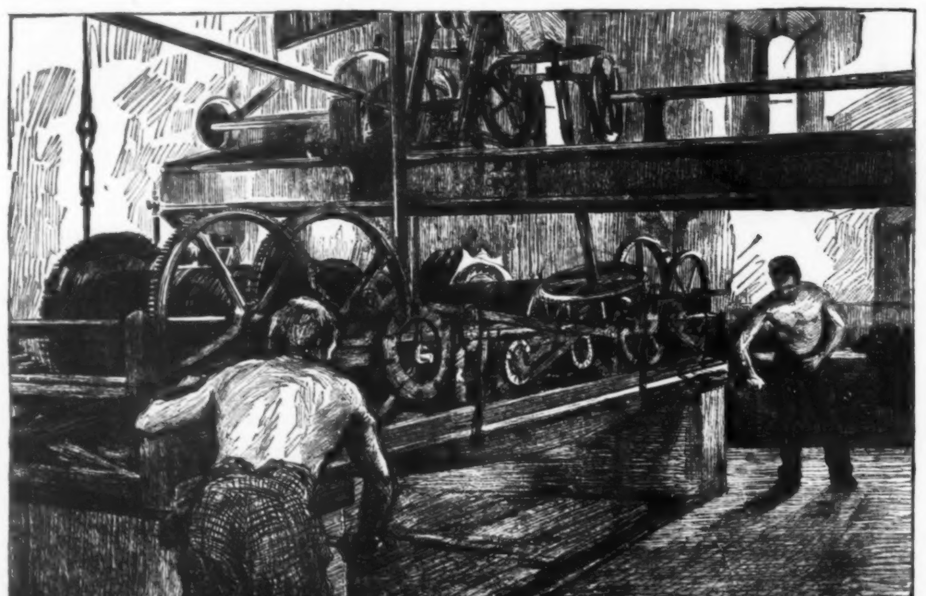
7. A roburite cartridge was placed on the side of an old wrought iron rail, and covered with a little earth. The rail was bent and completely perforated by the detonation of the roburite.

The result of the fourth of the above trials seems to the disadvantage of roburite in comparison with blasting gelatine. It was made at the special request of some of the colliery experts present, who stated, and, as it appears, correctly, that gelatine when fired in the water cartridge would not inflame loose gunpowder. It is, perhaps, but fair to insert at the same time the explanation given by Dr. Roth, who is admitted to be an able practical chemist. He states that the gunpowder was not fired by any flame or spark produced by the explosion of the roburite—which indeed the sharpest eyes have throughout failed to detect—but by the tremendous heat produced by the friction of the particles of the solid powder during the sudden, nay, practically instantaneous, expansion of the detonated roburite into its gaseous components. In the case of the water cartridge, there is an elastic cushion of superheated steam or vapor which prevents the ignition of the gunpowder. He further declares that no such effect can be produced upon firedamp by the explosion of roburite, since the former, being a compressible and elastic gas, yields to the blow caused by the sudden expansion. It may be mentioned in favor of this explanation that in the three separate sets of gas experiments carried out at three different collieries, in no instance has the explosive mixture of gas and air been fired by the explosion of the roburite itself. It is, however, much to be desired that careful trials should be made by some governmental or other independent authority, in no way interested in the result, except in so far as the production of a perfectly safe explosive for use in fiery coal mines is concerned. As to the experiments already carried out, it may be noticed that all the colliery managers, viewers, and other mining experts present represented fiery coal mines in which an ordinary shot of blasting powder cannot be fired. Even if it could be proved that roburite, when exploded by itself, could ignite firedamp, its advantages of safety in storing and handling, as well as its not freezing at any temperature, are so great that there is no reason why it should not be used inclosed in Settle's water envelope, like blasting gelatine. The cartridges in which it is packed can be soaked in water for a very considerable period without injuring the contents. As an instance, it may be stated that, in one of the shots fired at Silksworth recently, the roburite charge was left for three quarters of an hour in a hole full of water, through the electric exploder getting out of order. At the expiration of the above interval, the shot was fired with full effect.

In concluding our notice of these important experiments, it may be stated that roburite is not a single chemical compound like nitro-glycerine or gun cotton, the action of which on firedamp cannot be varied except by some superadded mechanical contrivance, such as the water cartridge, but that it possesses an artificial constitution—built up, so to speak, in such a manner as not to ignite an explosive atmosphere. It is the result of many years of labor on the part of the inventor, Dr. Roth. That gentleman first directed his attention to the methyl compounds—alcohols and glycerines—and endeavored to obtain from them a hydrocarbon constituent which, when mixed with some inorganic oxygen-yielding substance, such as potassium or ammonium nitrates, would not inflame firedamp. Some powerful explosives were thus produced, but these all—like the dynamite class—possessed elements of danger. He then turned to the so-called aromatic coal tar products, from which Designolles, Brugere, and Sprengel had produced powerful explosives, but they also were dangerous, either through being easily ignited by friction or by reason of one of the constituents having to be contained in hermetically sealed glass vessels. Dr. Roth now contends that he has succeeded in overcoming all these objections by his peculiar process of chlorinating and nitrating the coal tar products. It is quite true that benzol, phenol, etc., had been previously chemically combined with nitro groups, although the resulting substances were either too readily decomposable or else liable to ignite firedamp; but he has combined these nitrated products with another substance such that the resulting compound will, upon being detonated by fulminate of mercury in the usual manner, evolve gases which shall instantaneously quench any flame that may be produced by the explosion. In fact, the practical effect is somewhat similar to that produced by Settle's water cartridge, with the very important distinction that, through the quenching elements being chemically combined with the explosive, there can never be any risk of failure, as would incontestably be the result if the water envelope were not properly adjusted, or if, through being roughly tamped, the envelope were to be broken and the water escape. The organic substance in question is mixed with a certain proportion of ammonium nitrate, calculated to oxidize it completely, and, in the result, Dr. Roth claims to produce a practically flameless detonation, of a power equal to that given by any known explosive. Roburite has theoretically, by the dynamometer of Trauzl, nine times the force of gunpowder, and, practically in coal mining, its effect by weight is four times as great. The product of its gas volume and calories (units of heat) is given as 1,150,000, that of dynamite being about 950,000.—*Engineering*.



THE CHIMES—BIG BEN AND HIS LITTLE BROTHERS.



WINDING UP THE CLOCK.

## "BIG BEN" AND THE CLOCK TOWER, WESTMINSTER PALACE.

## "BIG BEN" AND THE WESTMINSTER CLOCK.

THIS clock is believed to be the most powerful in existence. It drives the hands of four dials, each 22 feet 6 inches in diameter; strikes the hours on a bell weighing 13½ tons, and chimes the quarters on four bells, weighing together about 8 tons, and it performs this work with marvelous accuracy.

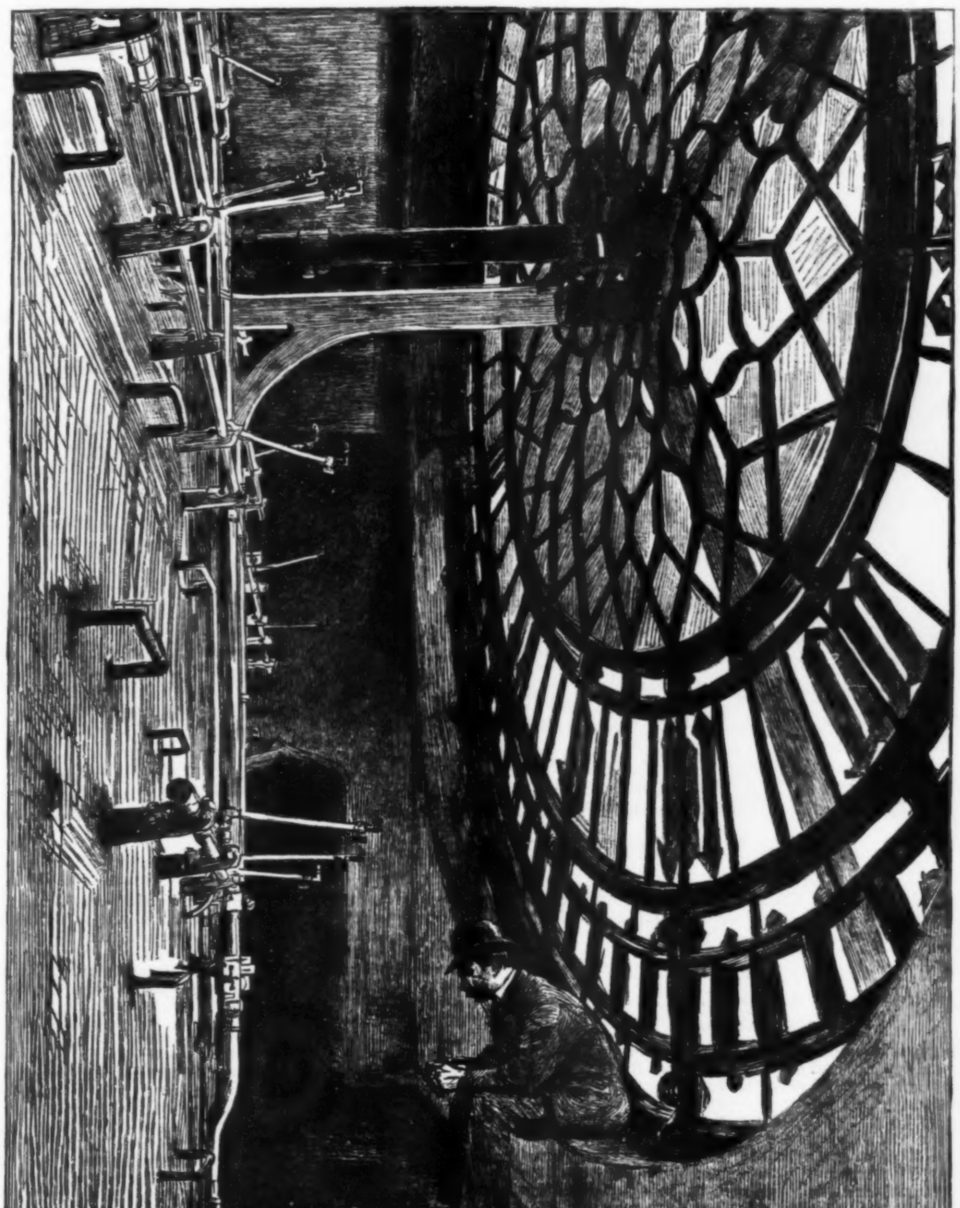
Its reputation as a time keeper is unrivaled and well deserved. This year it has surpassed all its previous performances, its accumulated error in 134 days having been less than four seconds, giving a mean variation of less than one second in a month, and this continuous during more than four months. For seventeen consec-

utive days it went without any perceptible variation whatever. The pendulum, the time measurer, is about 15 feet in length, and has a bob weighing about 700 lb. It is, of course, compensated for variations of temperature, zinc and iron being the metals employed. These are so disposed that the greater expansion of the zinc in any increase of temperature nullifies the lesser expansion of the greater length of iron, the actual expansions of the two metals being equal, but acting in opposite directions. The escapement of the clock, which gives impulse to the pendulum, and so keeps it in motion, is that known as Denison's double three-legged gravity. The advantage of this form of escapement is that it gives to the pendulum an impulse not subject to any variations such as would be caused by mechanical imperfections in the wheel-work, or from the action of the wind on the long hands, or differences in the friction produced by changes in the condition of the oil, any of which would tell on the going of the clock.

The driving weight of the going part of the clock is comparatively small, being about one hundredweight and a half. This, falling about two hundred feet, is sufficient to keep the clock going for eight days. It is wound up once every week.

The striking parts are much more ponderous. The hammer which at present strikes on the hour bell ("Big Ben") weighs about four hundredweight, but at one time a much heavier hammer was used. The weights of the hour-striking part and of the quarters weigh about three tons. These weights have a fall of about two hundred feet to keep the clock striking four days only. At one time these were wound twice each week, but the work is very laborious, and, to ease the men employed, the striking parts are generally wound three times each week. The striking is effected with very great precision, the first blow of the hour being struck at Greenwich time.

The clock is still under the care of its makers, Messrs. E. Dent & Co., of 61 Strand, who pride themselves on its accuracy. Time signals are sent to the clock tower from the Royal Observatory at Greenwich, for the purpose of enabling the attendants to verify the performance of the clock, which in its turn reports itself twice daily to the Astronomer Royal, under whose direction a record of its going is kept in the books of the Royal Observatory.



BEHIND THE CLOCK DIAL, WESTMINSTER PALACE.

The clock was erected in the tower in 1859. It is, of course, stopped at intervals of about four years, for the purpose of cleaning, and last year, when it was taken to pieces, its condition, after twenty-eight years of going, was found to be unimpaired, the only part showing any signs of wear being the auxiliary wheels used to facilitate the winding. Many years will probably elapse before even these will require to be renewed, and when this happens it will not even be necessary to stop the clock.

The dials, as we have said before, are 22 ft. 6 in. in diameter, over 70 ft. in circumference; the strokes or dots indicating the minutes are therefore 13 inches apart, so that the point of each of the minute hands travels over a distance equal to about one-third of a mile every day.

The hour bell is heard all over London, but, of course, this depends on the condition of the atmosphere, the wind carrying the sound in whichever direction it happens to be blowing.

The dials are illuminated, and mechanism was provided in the clock for the purpose of raising and lowering the gas, which was always kept burning, but it was found more economical to turn it off entirely during the day, and therefore it is now lighted each evening by an attendant.—*London Graphic.*

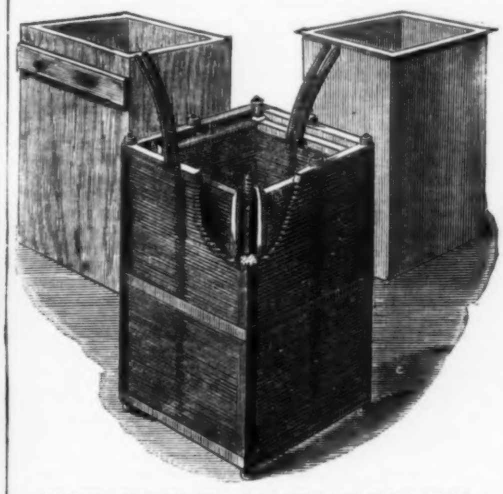
## ELIESON'S NEW SECONDARY BATTERY.

MR. ELIESON'S reasons for designing a new form of accumulator are based upon his recent experiences in tramcar propulsion. He has found that in practical working the present forms of batteries, including his own, on the principle of alternate, positive and negative, plates, are not likely to prove successful for any length of time for the purposes of electric locomotion. It appears that the chances of buckling and short-circuiting due to mechanical and electrical action have not yet been eliminated, and that the continuous vibration and jolting on the track will distort the best mechanical arrangement in a comparatively short time.

Up to the present no one has discovered a more suitable metal than lead, and this, owing to its weight, adds greatly to the distorting influences. Mr. Elieson, therefore, found it absolutely necessary to set to work and design a new form of cell which should secure a maximum of active surface with a minimum of weight, and, at the same time, insure a durability which does not seem obtainable under the known methods of construction. It will be seen from the drawing which accompanies this description that the battery of Mr. Elieson consists of but two electrodes, although for special purposes these may be increased. The cast lead frame of each is in the shape of a hollow square about 9 inches deep; the outer one being 6 inches and the inner 4½ inches square. Each side is filled up with longitudinal strips of lead foil separated, except in those points through which the bolts referred to below pass, as in the inventor's previous form of plate, by asbestos paper. The skeleton frame at each corner, and in the center of each side, is furnished with a tapped bolt, and when the lead foil is all built up a movable top clamp, also of cast lead, is placed over all, and the whole mass tightened up as desired by screw nuts of ebonite.

The two electrodes are placed one inside the other in a leaden box, being insulated from one another by thick India rubber bands stretched from top to bottom at each corner, and insulated from the bottom of the box by a cross piece of wood. The whole is contained in a teak case.

Mr. Elieson believes that the type of cell which he has submitted to us will fulfill all that is required for the purpose of electrical propulsion, but it is rash to prophesy with regard to the future of cells constructed for this special purpose. The weight of the two elements is 36 lb., and the surface exposed is estimated at 26,000 square inches. We hope that the inventor's be-



ELIESON'S NEW SECONDARY BATTERY.

lief that this form of cell marks another forward step in the production of a practically perfect accumulator for tramcars will be realized.—*Electrical Review.*

## THE MANUFACTURE OF ELECTRIC LIGHT CARBONS.

ALTHOUGH arc lighting in this country has not been introduced to anything like the extent prevailing in America, yet the quantity of arc light carbons consumed in Great Britain is by no means insignificant. Unfortunately for our home industries, by far the larger part of the supply of carbons is at present obtained from abroad, especially from America, whence come the more common and inferior brands, while France and Germany supply generally the better qualities. A certain amount of arc light carbons is also manufactured in England, but the industry is as yet of very small importance, and very little is known about the process of manufacture, the various makers having up to the present kept the technical details of carbon making as secret as possible.

To this rule there is, however, one exception, and that is the Liepmann Carbon Company, Limited, of Millwall, London, who recently threw their factory open to the inspection of a party of electricians and representatives of the scientific press, and have thus broken the spell, and dissipated the halo of mystery which hitherto has surrounded the making of carbons for arc lamps and batteries. After all, there is very little in this manufacture. The process is extremely simple, and the real secret of success is the use of very pure materials and an ample allowance of time for the different operations. It will probably surprise many of our readers to learn that the manufacture of each individual carbon pencil takes several weeks, and in some cases months, and that in consequence of this slow rate of progress an enormous stock of carbons in a semi-manufactured condition must always be on hand. In the compartively small works of the Leipmann Company no less than about 300,000 carbons are usually in course of manufacture at the same time.

The raw material most commonly used in the manufacture of inferior arc light carbons is either graphite, coke or retort carbon from gas works; but the large amount of mineral impurities unavoidably present give to the arc those colored tints and produce those flickerings which are so objectionable and fatiguing to the sight. Dr. Liepmann employs a raw material specially prepared by the distillation of shale or other mineral oil, for which he claims that it contains only carbon and hydrocarbons, and can be burned without leaving even a trace of ash.

This material is both soft and brittle, and is ground to an impalpable powder in a Carter's disintegrator. The carbon dust thus obtained is then baked to harden

each particle, and after mixing it with a specially prepared tar in an ordinary mortar mill, the plastic paste is ready for the press. At the works we inspected, the "squirting" of the carbons is performed on two horizontal hydraulic presses, one turning out solid and the other hollow cores, although by inserting suitable dies, carbons for batteries or other purposes can be made on the same machines. The combined capacity of these presses is 20,000 ft. of eleven millimeter carbons per week. Power is supplied by a steam engine working a three-throw pump in connection with a hydraulic accumulator, and the carbon paste while in the press is subjected to a pressure of about 5½ tons to the square inch. The charging is done by hand—a method which seems capable of improvement, not so much on account of economizing labor, as to avoid waste of material. The squirted carbon rod issues upon a table provided with rollers, and after about 4 ft. have been squirted the rod is cut by four knives carried in a frame into four 1 ft. lengths, which are stacked by the side of the table, with carbon dust between the layers to prevent the different rods sticking together. The next operation is that of air-drying, which takes several weeks, and after the carbons are thoroughly dry they are straightened, which is done by rolling them between boards after having been slightly heated to make them plastic. The shells for the cored carbons receive the core after drying. The core is simply squirted into the shell by a small hydraulic press; but this machine could not be shown in operation, owing to having been damaged at a recent fire.

The most important, and at the same time the most delicate, operation in the manufacture of arc light carbons is the baking. There are three furnaces (one principal and two auxiliary) for this purpose, all heated by gas made in a Wilson's gas generator. The use of gas for firing these furnaces is almost an absolute necessity, since it is important to have the heat under perfect control, which could scarcely be done by the employment of solid fuel. The carbons are stacked upon an iron trolley, which is slowly passed through the principal furnace, entering at the coolest end. There are five zones of heat in this furnace, and the carbons are passed through these in about one week. After leaving the hottest zone in the principal furnace they are placed in one of the two auxiliary furnaces, which is gradually let down, so as to cool the carbons as slowly as possible.

A carbon after having passed through these various stages of manufacture is practically finished, but it is not yet ready for the market. The ends must be trimmed, in some cases the carbon must be copper plated, and it must be tested for resistance. The latter operation is, we believe, not generally carried out in other works; but Dr. Leipmann has devised so simple and expeditious a method of testing, that this operation involves scarcely any additional delay or expense, and is consequently invariably performed. The testing apparatus sorts the carbons automatically, those having the standard resistance or less being dropped into one box, and those having too high a resistance into another. The apparatus consists of a wooden drum about 8 in. diam., and slightly longer than a carbon, mounted below a hopper, into which the carbons to be tested are placed. The slot at the bottom of the hopper is only wide enough to admit one carbon to the drum at a time, and the latter is provided with longitudinal grooves, into which the carbons are dropped, and thus carried forward. Besides the longitudinal grooves, there are three circumferential grooves, and corresponding with them in position are three curved iron spikes attached to a horizontal shaft, which is controlled by a solenoid and spring. By means of this shaft the ends of the spikes may be either brought to lie tangentially within the grooves, or may be raised clear of the cylinder; and according to the position of the spikes, each carbon, as it drops out of its longitudinal groove, falls either in front or behind them, and is thus directed into either of two boxes placed below the cylinder. Current is supplied to the solenoid from the low tension Brush machine, which works the copper plating tanks in an adjoining room, and rubbing contacts are provided at each end of the wooden cylinder, whereby each carbon as it approaches the position where it drops out of the horizontal groove is, for a moment, inserted as a shunt to the solenoid. As there is a resistance in the circuit before it branches out to this solenoid and the rubbing contact, it follows that the lower the resistance of the carbon, the less must be the current passing round the coils of the solenoid. The iron core of the latter tends to keep the spikes within the grooves, and a counteracting spring tends to lift them out. If now the carbon shunting a portion of the current has more resistance than it should have (about 0·2 ohm for a carbon of 11 mm.), the core is pulled in with sufficient force to keep the spikes within the grooves, and the carbon falls into the front box and is rejected. If, however, the resistance is low, the spring overcomes the sucking power of the solenoid, and the spikes are lifted out of their grooves, allowing the carbon to fall into the other box.

The copper plating of carbons is also a very expeditious operation. There are eight sliding frames, each carrying a row of spring clips, by which the carbons are suspended, and below these is a corresponding number of cylindrical glass vessels, containing each a copper cylinder, and filled with dilute sulphuric acid. The copper cylinder forms one electrode, and each carbon, when the frame is lowered so as to immerse it in the liquid, forms the other. The current is switched on automatically by a sliding contact when the frame is lowered, and the attendant judges the time required to from a sufficient coating by the color of the deposit.

The Liepmann Company make also a specialty of the manufacture of Leclanche cells, or rather of the inner portions of these cells, viz., the porous pot containing the carbon electrode embedded in carbon and binoxide of manganese. On the top of the carbon plate which protrudes through the sealed-up cover is cast a lead shoe with terminal screw ready to be placed into the glass jar. Another specialty at the works is the manufacture of the Liepmann primary battery, a zinc carbon bichromate cell, of which various types are being made. The only special feature about these cells is the arrangement of the carbon electrodes, which, instead of being solid slabs, are composed of a series of carbon rods united at the top by a lead shoe and at the bottom by insulating material, the latter to provide mechanical strength. Dr. Leipmann claims that by thus subdividing the carbon electrode, and presenting a greater surface for contact with the chromic acid, the constancy of the battery is much increased. According to the purpose for which the battery is intended, porous pots of different densities are used. For a battery giving a quick discharge, pots of more open texture, having a low resistance, are preferable; but for continuous work, and especially if the battery is left standing idle for longer or shorter intervals, it is preferable to use denser pots, having more internal resistance, as thereby the evil of local action is diminished. The largest sized cell we saw is said to have a capacity of 600 ampere hours, giving an external e. m. f. of 2 volts, which, with a discharge of from 3 to 4 amperes, falls after a time to 1·8 volts. After giving 60 ampere hours the inner solution of dilute sulphuric acid must be renewed. The outer solution of chromic acid must be renewed after 600 ampere hours, and the whole of the zinc is consumed after 2,400 ampere hours.—*Industries.*

## AN EARTHQUAKE RAILWAY STATION.

ON the 4th of August last, at 11:30 A.M., an earthquake occurred at San Mateo station, on the Oroya Railway, Peru. This station, the last but one on the line, is about 12,000 feet above the sea. In this part of the mountains frequent earthquakes are experienced, which sometimes do much damage and interrupt railway travel for many days together. On the day above mentioned the station house was almost ruined. The agent, who lived in the building with his family, barely escaped with life. Quantities of stones and earth fell upon the house. We are indebted to *El Peru Ilustrado* for our engraving.

AN EARTHQUAKE RAILWAY STATION.

## GEMS AND PRECIOUS STONES.*

By GEORGE F. KUNZ.

### THE DIAMOND.

THE most valuable of precious stones is the diamond —pure crystallized carbon—the most highly refractive and the hardest of gems, and the only one that is combustible. This latter property was discovered in 1691 by Cosmo III. of Tuscany, who ignited the diamond with a burning glass; and later it was found that when burned in a crucible this gem converts iron into steel. The diamond generally occurs as an octahedron, and surpasses all other gems in the property of dividing light into colored rays, causing that peculiar flash of prismatic hues called its *fire*.

Diamonds are rated by the *carat*. The term carat is derived from the name of certain small leguminous seeds which, when dried, are quite constant in weight. They were used in India for weighing gems.

In 1871, the syndicate of Parisian jewelers, goldsmiths, and gem dealers suggested 0·205 of a gramme as the value of a carat; and this was confirmed in 1877, all the leading diamond dealers of London, Paris, and Amsterdam accepting it. The English carat is equal to 3·1683+ grains (commonly reckoned as 3·17 grains) troy. Hence there are 151½ carats in an English troy ounce. The jewelers' carat is subdivided into halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. A quarter carat is called a grain. Pearls are always sold by the grain.

The earliest known mention of diamonds is supposed to be that in the Indian epic "Mahabharata," B. C. 1,000. Before 1728, the date of the discovery of the Brazilian mines, all diamonds were brought from India and Borneo. There are three distinct diamond-producing regions in India. The familiar word Golconda is not the name of a mine, as popularly supposed, but merely the general term for the market where diamonds were bought and sold. To-day all the mines are nearly closed.

Indian diamonds occur in a conglomerate, and also in alluvial or superficial deposits, together with pebbles, ferruginous quartz, and jasper. Early methods of mining were very crude. The conglomerate was dug out and carried to small square reservoirs, raised on mounds, where it was carefully washed and sorted, the wet diamonds being readily recognized by their peculiar vitreous luster.

At present India yields very few stones, while Borneo produces only about three thousand carats annually. Diamonds are also mined in New South Wales, and are met with in California, the Ural Mountains, North Carolina, and Georgia. In 1856, the "Dewey Diamond," that cut eleven and a half carats, was found near Manchester, Virginia.

### SOUTH AFRICAN DIAMOND FIELDS.

By far the greatest portion of the diamonds now obtained come from the mines of South Africa, which were discovered, near Hopetown, in 1867, by some Dutch children. They are situated in Griqualand West, now a part of Cape Colony, in latitude 28° 40', longitude 25° 10' east, about 640 miles northeast of Cape Town and 500 miles from the sea coast. Although they are at an elevation of nearly 4,000 feet above the sea level, the heat is excessive during the summer months, when the work is principally carried on. There are four large mines, all within a radius of a mile and a half. The celebrated Kimberley covers seven and a half acres.

The African mines were originally worked in individual claims, 3,143 in number, each 31 feet square, with a roadway seven and a half feet wide between each pair of claims. These small claims are now consolidated into about ninety large companies and private firms, having a gross capital of nearly $50,000,000. Thirty-three million carats (over six and a half tons) of diamonds have already been taken out, valued in the rough at £45,000,000, and after cutting at £90,000,000. The absorption of the smaller by the larger companies (*unification*) is constantly going on, and it is proposed to consolidate all the companies into one gigantic monopoly.

Ten thousand natives, each receiving one pound a week, are employed in the mines under the supervision of twelve hundred European overseers.

The enormous sum of over £1,000,000 is annually expended for labor. This mammoth investment of European capital has been profitable to the shareholder, and it would have been still more so were it not for the thievishness of the native diggers, who, instigated by the vicious whites that congregate on the fields, steal and dispose of from one fifth to one fourth of the entire yield. More improved methods of surveillance, recently introduced, notably the compound system, by which the natives are confined in the company's care during the period of contract, have diminished this loss. None but authorized agents are permitted to purchase or possess rough diamonds, and a large detective force is on the alert to prevent any infringement of the rules. The lengths to which the natives and their white accomplices go in their fraudulent traffic may be judged from the fact that chickens have been decoyed to the mines by them and made to swallow diamonds. A *post mortem* recently held on the body of a Caffre, who had died suddenly, revealed the fact that death was caused by a sixty carat diamond which the native had swallowed.

### THEORY OF FORMATION.

At the Kimberley mines, the diamonds were first obtained on the surface in a yellow earth, the result of the decomposition of strata found 100 feet below, and known as "blue stuff." Scattered through it are angular pieces of carbonaceous shale, garnet, mica, etc. At a depth of 600 feet, a hard rock (peridotite) was found, containing the same shale. This shale has evidently been altered by the action of heat produced by the penetration of the volcanic rock through it; and this heat, causing the liberation of some volatile hydrocarbon, has doubtless produced the diamond. The mines are so surrounded by carbonaceous shale that they form, as it were, "pipes" in the center of it.

In the Kimberley mine a depth of 600 feet has been reached. The number of obstacles which have been successfully overcome, and the novel machinery in use, make the mining at Kimberley the most systematic of the kind in the world. Progress has been rapid. On the site of the desert there is now a city of 25,000 inhabitants, with water works, railroads to the coast, and many other improvements of modern civilization.

### BRAZILIAN MINES.

In Brazil diamonds are found in several localities. At Diamantina, in Minas-Geraes, 4,000 feet above the sea, the stones occur usually in the gravel and sands resulting from disintegrated rock. Up to 1850, over 7,000,000 carats, worth £11,000,000, had been taken from the Minas-Geraes mines alone. Perhaps the entire yield from Brazil may be estimated at 13,000,000 carats, worth £20,000,000.

The beds of rivers have been turned aside to aid in

*Written for the second edition Appleton's Physical Geography, and thus published in advance by special permission.

the search for diamonds, but the methods of mining have always been very crude. Little machinery has been used, the work of sorting being performed by slaves, who were rewarded for any exceptional find.

### REMARKABLE DIAMONDS.

Some diamonds are celebrated for their size or the interesting legends connected with them. The Regent, or Pitt diamond, weighing $136\frac{14}{16}$ carats, and originally purchased by Lord Pitt for £1,000, is the finest large diamond in the world. It was discovered in India in 1701, and weighed 410 carats in the rough. Valued at 12,000,000 francs, it was one of the few valuable French crown jewels retained by the government at the great sale in May, 1887, which netted 7,220,000 francs.

The finest blue diamond is the "Hope," which is almost sapphire blue and weighs $44\frac{1}{4}$ carats. It is an Indian stone and evidently part of Tavernier's blue diamond, which was stolen from the Garde Meuble in 1792. It was purchased by Mr. Henry Hope for £18,000. The Dresden Green Vaults contain the finest green diamond, a pear shaped $48\frac{1}{2}$ carat brilliant, the "Dresden Green."

Among the largest diamonds is the Orloff, in the scepter of the Emperor of Russia, weighing 193 carats. It is fabled once to have formed the eye of an Indian idol, and to have been stolen by a French deserter. In the Russian treasury is also the Shah, 86 carats. Tavernier's Great Table weighed $242\frac{5}{16}$ carats.

The Tiffany yellow diamond, the largest diamond in America, is a flawless double cut brilliant. It was found in South Africa, weighs $125\frac{3}{8}$ carats, is of a rich orange yellow color, and is the finest yellow diamond in the world. It is valued at $100,000.

The "Great Mogul" was described by Tavernier, the famous traveler, in 1678. He states that its weight was originally $793\frac{5}{8}$ carats, but in cutting it was reduced to $279\frac{9}{16}$ through the stupidity of the cutter, who is said to have been fined his entire fortune for his carelessness. This magnificent stone was named after the founder of the so-called Mogul dynasty in India. It has disappeared, though some identify it with the Koh-i-Nur (Mountain of Light), which weighed when first brought to England $186\frac{1}{16}$ carats, but was reduced by recutting, in 1852, to $106\frac{1}{16}$ carats. The Koh-i-Nur, "the great diamond of romance," is now among the English crown jewels. Barbot valued it before recutting at £140,0 0.

A diamond weighing $457\frac{1}{2}$ carats was brought from the Cape in 1884. It has been cut into a brilliant weighing 180 carats. The finding of this great stone is enveloped in mystery. The name "Victoria" or "Imperial" was given to it in honor of the Queen, and it is undoubtedly the largest brilliant in the world. It is valued at £200,000.

### VALUE OF DIAMONDS.

In diamonds, perfectly white stones or decided tints of red, rose, green, or blue are most highly prized. Fine cinnamon and salmon or brown, black, or yellow stones are also esteemed. If flawless and without tint of any kind, they are termed "first water." If they possess a steely blue color, at times almost opalescent, they are called blue white. Such are usually Brazilian stones. Exceptionally perfect stones are termed gems, and for such there is no fixed value, the price depending on the purity and the brilliancy of the stone.

The term "first water" varies in meaning according to the class of goods carried by the dealer using it. It is impossible to estimate the value of a diamond by its weight—color, brilliancy, cut, and general perfection of the stone are all to be taken into account. Of two stones, both flawless and weighing ten carats, one may be worth $600, and the other $12,000. Exceptional stones often bring special prices, whereas off-color or imperfect stones sell at from $50 to $75 per carat, regardless of size.

The probable value of all the diamonds in the world is about $1,000,000,000. The world's diamond trade is carried on by about eight thousand dealers, with a total stock of not far from $350,000,000. The stones are prepared for market by perhaps forty-five hundred cutters and polishers, principally in Amsterdam, Antwerp, Paris, and the Jura. A limited amount of cutting is also done in England and the United States.

The ruby and the sapphire are varieties of the species corundum. The yellow variety is known as Oriental topaz, the green as Oriental emerald, and the purple as Oriental amethyst. The two latter forms are rare. The sapphire belongs to the hexagonal system, is next to the diamond in hardness, and is composed of nearly pure alumina.

The most highly valued rubies, which are of the color of pigeon's blood, are found near Mandelay, in Burma. In Ceylon they occur of a lighter color, and in Siam of a very dark red. Although the diamond is more generally esteemed, the rarity of rubies of from three to four carats weight is such that they are worth five to ten times as much as diamonds of the same size. The choicest colors of the sapphire are the cornflower and the velvet blue.

The chrysoberyl gems, next to the sapphire in hardness, include the varieties of yellow, brown, green, and an endless number of intermediate shades. The variety of chrysoberyl in which impurities are found between the layers, or the layers are so arranged by twinning that, if the stone is cut across the layers, the light is condensed in an even line, is called chrysoberyl cat's eye, and it is dark olive green by day, and columbine red by artificial light (alexandrite).

Beryl is a silicate of glucina and alumina. Golden colored beryl is found in Maine, Pennsylvania, and Connecticut. When the beryl is colored with chromium, we have the emerald. The finest emeralds are from the Muso mine, near Bogota, where they occur in a rock containing bituminous concretions filled with fossils. This mine has been worked for the past three centuries by Europeans, and was previously operated by natives and ancient Peruvians.

Some of the finest crystals of emerald known have been found in Alexander County, North Carolina. One weighing ten ounces, but of small gem value, has been found there. When really fine and flawless, emeralds rank with diamonds in value.

Topaz occurs yellow, blue, cherry, green, and white. Tourmalines are found in Brazil, Siberia, and in remarkable perfection at Paris and Auburn, Me.

Quartz gems are pure silica colored by iron or other oxides. When pellucid, the crystalline varieties are called rock crystal. When colored purple or violet by oxide of manganese, amethyst. The crypto-crystalline varieties of quartz are chalcedony, gray, bluish gray, or brown, with a waxy luster. When banded with rock crystal, jasper, etc., it is called agate. When translucent like horn, yellow, yellowish brown, or red, it is called carnelian. When in bands of white, gray, and other colors, it is called onyx (used for cameos); with moss-like markings produced by oxide of manganese or iron, moss-agate. Moss-agate occurs in immense quantities in parts of the West. Agatized wood (in which the wood fibers are changed to agate by the infiltration of silicious waters) is found in Arizona and the Yellowstone Park.

Noble opal is milky, almost opaque, with a play of brilliant, red, green, orange, and other hues. Hungary, Honduras, and Mexico are the localities for this stone. When yellow, red, and green colors combine like flashes of fire, the name fire opal is given to it. This species is found mostly in Mexico. California furnishes beautiful opalized wood.

Pearls are small bodies found either in mother-of-pearl shells or in those with a nacreous lining. They are formed either by a disease, by the presence of a parasite, or by an effort on the part of the mollusk to rid itself of some foreign substance which has found its way into the shell.

Pearls are composed of many layers of carbonate of lime with organic matter between, are not always entirely pearly throughout, and invariably have some small central core or nucleus. Round pearls of fine luster and color are very valuable, and their value increases rapidly with their size.

The finest white pearls are from India, the Persian Gulf, and Panama; the finest black and gray pearls from the coast of Lower California. Beautiful pink tinted pearls are often secreted by the common brook mussels, the common conch, or *Strombus gigas*. One valued at over $2,000 was found near Paterson, N. J., in 1856, and quite a number have been met with in Ohio, Tennessee, Kentucky, and Texas, and also in England, Scotland, and Germany.

THE SNOWDROP TREE (HALESIA TETRAPTERA). (FLOWERING TWIG, NATURAL SIZE.)

The forms in which gems are cut are divided into two groups—those with plane and those with round surfaces. To the first belong the brilliant, step or trap cut, and the table cut or rose cut; to the second, the single, the double, and the hollow cabochon or carbuncle cut.

The brilliant cut is usually modified, but when perfect fifty-eight facets are required—thirty-three constituting what is called the crown or upper part, the large facet being termed the table, and twenty-five the back pavilion, or base. The small facet at the bottom is called the collet or culet, and the edge of the stone the girdle. This form of cut is most extensively used for diamonds, but is occasionally employed for other stones.

Emeralds, rubies, sapphires, and other colored stones usually have the step cut, so called from the fact that the facets on the crown are in a step-like series, and below the girdle are three or more diminishing zones terminating in a culet. The encabochon or carbuncle cut is that in which the top is rounded off and the back flat, hollowed out, or the same as the top. Garnets, turquoises, opals, cat's eyes, are cut in this manner. In the rose cut, the back is flat and the top covered with triangular facets, generally from twelve to twenty-four in number.

### IMITATION STONES.

Rhinestones, the Lake George, California, Swiss, and Swedish diamonds, with the so-called diamond-coated stones, are all paste or lead glass.

These imitations have been recently improved by the addition of little metal cups or coatings filled with mercury, for which reason they are known as foil backs, brilliants, etc., but the hardness of all is below that of flint glass. Paste gems are made of silica and oxide of lead, colored with metallic oxides to produce the required shade of color.

In doublets, the crown is made of quartz, garnet, or some equally cheap and hard stone; but all below this is paste of the desired color, the two parts being joined by cement or fire.

Imitation pearls are small, blown spheres of slightly opalescent glass, roughened and lined with a preparation made from the scales of a small fish found in Switzerland (the bleak), and then filled with wax.

## THE SNOWDROP TREE.

### (HALESIA TETRAPTERA.)

THIS is one of those interesting old-fashioned trees that one meets with now and again in very old gardens. It is far from being common, for, though it is still procurable from our best tree nurseries, it is, nurserymen tell me, seldom asked for, so seldom, in fact, that it hardly pays them to keep what little stock they grow of it in a condition for transplanting. Why such apathy prevails in regard to these old trees is not to be accounted for, except from the fact that the majority of landscape gardeners, who have more opportunity for planting than anybody else, are ignorant of trees and shrubs beyond the ordinary stock in nurseries. This tree, besides a host of others, should be planted in every important garden, and if such were the case what a great amount of interest and beauty would be added thereto!

It is not often that one meets with the snowdrop tree in a perfectly happy condition, and it is only where is has been planted in a moist and sheltered spot that it seems quite at home. A dry soil or an exposed position is foreign to its nature, and from the fact that it grows wild on river banks in Carolina and Virginia, it should always be planted in a moist spot. The finest snowdrop tree I have ever seen I think was growing at Trentham by the margin of a lake, where its roots must have been perpetually in very moist if not absolutely wet soil. This particular specimen was a beautiful tree of graceful habit, having a dense head about twenty feet across and as much in height, and bore that appearance indicating rude health.

In a dry soil, such, for example, as the hungry light soil in the Kew Arboretum, it is a miserable tree, growing certainly, but never thriving luxuriantly. Besides moisture, it seems to revel in a rich soil, such as the alluvium of river banks and lake margins, and as such a soil can be found on nearly all estates, there need be no difficulty in the matter. This tree and the catalpa go well together, for both delight in a moist, rich soil, and two more suitable trees for a lake or stream margin could not be named. The snowdrop tree arrays itself in myriads of pearly white bells in spring, while the catalpa is about the only tree that flowers in August and September. The winged fruits of the snowdrop tree, being about an inch long and very numerous, have an interesting appearance during summer and autumn.

The pretty cut of the snowdrop tree which we here give we saw in *Vick's Magazine*, and have to thank Messrs. Vick for the use of it. It gives an idea of the beauty of a flowering spray of a snowdrop tree when it blooms in perfection, and as every branch and twig are laden in a like manner, one can imagine the appearance of a tree twenty feet high in full bloom. The form of the flower, its size, its snowy whiteness, and its always drooping form suggested, no doubt, the pretty name, snowdrop tree, as the flowers resemble snowdrops. In America it is also called the silver bell tree. It blooms in April and May, and American friends tell me that the trees which fringe the rivers in the Southern States have much the same appearance as our hawthorn trees do in bloom, so abundant are the flowers. It was one of the earliest foreign trees introduced to this country, as it was known in 1756, and might have been imported before that date. Loudon recorded, in his "Arboretum Britannicum," published in 1838, the heights and dimensions of some of the largest snowdrop trees in this country at that time, and as these trees may still be alive, it would be interesting to see what growth they have made in fifty years. There were at Syon House and Purser's Cross trees thirty feet high, with stems from sixteen inches to eighteen inches in diameter. At Bagshot Park, growing in sandy loam, was a tree twenty feet high after twenty years' growth; at Trentham, fifteen feet high, planted twenty-six years; at Alton Towers, ten years planted, fifteen feet high; at Ampton Hall, Suffolk, eight feet high, ten years planted. In Scotland there were trees at Thainston, Aberdeenshire, Toward Castle, Argyllshire, Huntly Lodge, Banffshire, but none were over twelve feet high, the tree not being perfectly hardy so far north. In Ireland there was a good tree at Ballyleady, County Down. It would afford valuable information if these same trees could be measured now, and I should be glad if any reader could furnish me with it. It may be gathered from this statement that the average rate of growth of the tree is about one foot a year, so that it is as rapid in growth as most trees. Loudon states that the price of the tree in the London nurseries fifty years ago was 1s. 6d., and, taking up the first tree catalogue to hand, I find it is just the same price now. It is easily propagated by seed, which ripens in this country in most seasons, and seed is also imported from the United States.

The Halesia tetraptera is the best known species, but there are two others, H. diptera and H. parviflora. Both resemble H. tetraptera, the difference in H. diptera being chiefly the two-winged instead of four-winged seed vessel. H. parviflora, as its name implies, has smaller flowers than H. tetraptera, and may be only a variety of that species. As neither H. diptera nor H. parviflora can be bought in English nurseries, little need be said about them, especially as H. tetraptera is the most ornamental.—*W. G., in the Garden.*

## THE COMPARATIVE DELICACY OF SOME QUALITATIVE TESTS.

By J. S. C. WELLS.

I HAVE so often been shown tests by students, and asked if they indicated any appreciable quantity of the substance tested for, that I have thought it might be of interest to know just how delicate some of the more important tests are.

I have begun with the metals of the fifth group (according to Fresenius), and the accompanying tables show the results obtained. Many tests might, no doubt, have been carried even farther than shown in table by using larger quantities of liquid and allowing them to stand for a longer time. My idea, however, was to obtain results such as any student might, with the ordinary apparatus used by him. For this reason the tests were all made in the ordinary six-inch test tube, and, unless otherwise stated, were not let stand more than five minutes.

It will be seen from the table that nearly all show, even in very dilute solutions, and that some of them,

such as the precipitation of lead by $H_2S$, are wonderfully delicate. It should be remembered that the results given were obtained in solutions containing nothing but the substance tested for and the reagent; no foreign substances being present. The results in column I. show the point beyond which it was impossible to distinguish distinct particles of the precipitate. After passing this point the reaction was indicated by a mere cloudiness or color. In column II. is shown the extreme limit of the test, that is, the most dilute solution in which any reaction was obtainable. In order to get a clear idea of how dilute such solutions are, it may be well to state that one part in one million is equivalent to one grain in seventeen gallons.

SILVER (Ag).

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $NH_4Cl$ | 1 | 20,000 | 1 | 250,000 |
| $HCl$ | 1 | 20,000 | 1 | 250,000 |
| $KBr$ | 1 | 20,000 | 1 | 200,000 |
| $KI$ | 1 | 5,000* | 1 | 200,000 |
| $H_2S$ | 1 | 5,000 | 1 | 800,000 |
| $K_2Cr_2O_7$ | 1 | 3,000 | 1 | 3,000 |

MERCURY (Hg).

$Hg_2O$.

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $NH_4Cl$ | 1 | 25,000 | 1 | 200,000 |
| $HCl$ | 1 | 25,000 | 1 | 200,000 |
| $H_2S$ | 1 | 5,000 | 1 | 1,000,000 |
| $NH_4OH$ | 1 | 25,000 | 1 | 25,000 |
| $SnCl_2$ | 1 | 50,000 | 1 | 200,000 |
| $K_2Cr_2O_7$ | 1 | 20,000 | 1 | 100,000 |

HgO.

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $H_2S$ | 1 | 2,000 | 1 | 1,000,000 |
| $NH_4OH$ | 1 | 4,000 | 1 | 4,000 |
| $SnCl_2$ | 1 | 50,000 | 1 | 200,000 |
| Cu | 1 | 10,000† | | |

LEAD (Pb).

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $HCl$ | 1 | 500 | 1 | 500 |
| $NH_4Cl$ | 1 | 600 | 1 | 600 |
| $H_2S$ | 1 | 20,000 | 1 | 1,000,000‡ |
| $H_2S$ in KOH solu'n. | – | —— | 1 | 1,000,000‡ |
| $H_2SO_4$ | 1 | 10,000 | 1 | 20,000§ |
| $K_2Cr_2O_7$ | 1 | 10,000 | 1 | 100,000 |

BISMUTH (Bi).

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $H_2S$ | 1 | 13,000 | 1 | 1,000,000 |
| $NH_4OH$ | 1 | 10,000 | 1 | 12,000§ |
| $H_2O$ ‖ | 1 | 10,000 | 1 | 90,000 |
| $K_2SnO_2$ ¶ | 1 | 40,000 | 1 | 90,000 |

COPPER (Cu).

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $H_2S$ | 1 | 2,000 | 1 | 1,000,000 |
| $NH_4OH$ | – | —— | 1 | 80,000 |
| $K_4FeCy_6$ | 1 | 2,000 | 1 | 1,000,000 |

CADMIUM (Cd).

| Reagent. | I. Part of substance. | I. Parts of water. | II. Part of substance. | II. Parts of water. |
|---|---|---|---|---|
| $H_2S$ | 1 | 4,000 | 1 | 200,000 |
| $H_2S+HCl$ ** | 1 | 20,000 | 1 | 200,000 |
| $K_4FeCy_6$ | – | —— | 1 | 4,000 |

Qualitative Laboratory, School of Mines.

* Only shows on standing some minutes.

† Shows in solution of 1-100,000 after standing four hours.

‡ Seen only on looking down the tube.

§ Only on standing a few minutes.

‖ This test was made on a solution of $Bi(NO_3)_3$ in presence of $NH_4Cl$.

¶ This is the test with KOH and $SnCl_2$, yielding $Bi_2O_3$.

** I found that the addition of a few drops of HCl made the precipitate separate much better than it would in either alkaline or neutral solutions.

## ON A NEW METHOD OF EXAMINING BUTTER.

By THOMAS T. P. BRUCE WARREN.

I INTENTIONALLY omit many preliminary points in connection with butter examination, although I do not ignore their value.

Ten grammes of the butter is carefully weighed and transferred to a tared filter tube, plugged with asbestos, which has previously been well washed with carbon disulphide to remove any loose fragments of asbestos; the plugged tube is then carefully dried and weighed. About 100 c. c. of pure carbon disulphide, or more if required, are poured over the butter gradually and allowed to filter through, more disulphide is added, so as to remove every trace of fatty matter.

The filtrate is received in a tared porcelain basin, which is carefully evaporated over hot water. When every trace of solvent has been removed it is cooled and again weighed. The difference between this and the original weight is due to salt, caseine, water, extractive coloring matter, which has been added, etc., insoluble in disulphide carbon.

The fatty matter is again dissolved in about its own volume of disulphide carbon, and the same volume of yellow chloride sulphur diluted with an equal measure of disulphide carbon added with constant stirring. The disulphide is completely evaporated over hot water. This part of the process insures the reaction of the chloride sulphur.

The resulting thickened mass should yield a perfectly clear solution with disulphide carbon. An insoluble residue will indicate the presence of any vegetable oil, notably those which are used in the maufacture of oleomargarine or butterine. In fact, it is absolutely impossible to add to or to substitute for butter any vegetable oil product with which I am at present acquainted.

The filter tube is carefully dried and then weighed. To the weight of the residuum in the tube is added the weight of the fat extracted. The loss from the original weight is that of the water. It is next treated with warm distilled water, which will dissolve out the salt and coloring matter. According to the color of the fat itself and quantity of coloring matter, an insight may be gained as to what the original butter was when it left the churn, at least before being churned with "the chemicals." It does not, of necessity, point to adulteration, as coloring matter is frequently added to improve the appearance of the real dairy product. The filter tube is finally washed out with dilute liq. ammonia, until every trace of caseine has been removed, which may be reprecipitated with hydrochloric acid, collected on a tared filter, dried and weighed. Water is passed through the tube, which is then dried and weighed. Starch or any other foreign matter not previously removed can easily be detected.

In examining good samples of country butter in this way I have been struck with the large amounts of caseine present. In one sample obtained from a respectable family grocer, and for which 20d. per lb. was paid, I found 15 per cent. caseine and about 85 per cent. soluble fats, with traces of water, salt, and a yellowish coloring matter.

I am not aware that caseine has been referred to by English chemists as an important adulterant of butter, but Chateau speaks of "lait durci au feu" as a source of fraud. I propose on a future occasion to examine this portion of the subject more minutely.

It seems to me that chambers of agriculture may well take this matter up, for if the mischief is produced by the real dairy farmer, the sooner it is stopped the better. I am, however, inclined to think that we must look to another quarter for this fraud.

Many dairy farmers do not work up their own milk, but sell the same to some manufacturing firm, who manipulate the milk for the recovery of curd, etc. This is a fraud which does a great injustice to the dairy farmer and to the agricultural interest in particular, to say nothing of the consumer.

If we are to contend with the fraudulent sale of oleomargarine as butter, we must impress on those whose interest it concerns that there must be no tampering with the product yielded by good, wholesome milk.

The *permissive character* of legislation on such subjects connected with adulterations has done more toward the depravity of our national candor than one cares to think about too much.

Animal fats, such as lard, lard oil, etc., behave very much like butter, and are so far capable of being blended with it, but the tests already in use amply provide against this source of fraud.

I may just say that the fearful frauds now practiced with lard oil, and the addition of resin or resin oil in any form, and also petroleum, to any vegetable oil, are instantly detected by this method of testing.

Are our oil experts aware of the incentive to dishonesty which they hold out to unscrupulous venders? Chloride of sulphur has been recently condemned for this purpose of testing oils. I suppose it clashes too severely with the interest of the oil trade. I simply protest against any chemist using his position as an ægis for the questionable practice of others.

I am indebted to Mr. Edwin Bruce Warren for the experimental data on which this paper is founded. I hope to deal more fully with this subject, and to consider the influences, etc., which may modify this reaction.—*Chem. News.*



## DIAMONDS IN METEORIC STONES.

IN a Russian paper appears a preliminary report of the examination by Latschinof and Jerofeif, professors of mineralogy and chemistry, respectively, of a meteoric stone weighing four pounds, which fell in the district of Krasnoslobodsk, government of Penza, Russia, on September 4, 1886. In the insoluble residue small corpuscles showing traces of polarization were observed. They are harder than corundum, and have density and other characters of the diamond. The corpuscles are said to amount to 1 per cent of the meteoric stone. Carbon in its amorphous graphitic form has been long known as a constituent of meteoric irons and stones; lately, small but well defined crystals of graphitic carbon, having forms often presented by the diamond, were described in our columns as having been found in a meteoric iron from Western Australia. "If this supplementary discovery be confirmed," says *Nature*, "we may at last be placed on the track of the artificial production of precious stones."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